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PRECIOUS METAL ENRICHED SKARNS IN BRITISH COLUMBIA:
AN OVERVIEW AND GEOLOGICAL STUDY

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ABSTRACT

Over 350 skarn occurrences are known to exist in British Columbia and at least 126 are enriched in precious metals. Of these, 49 precious-metal-enriched (PME) skarn deposits have produced a total of 342 tonnes of silver and 95 tonnes of gold, the latter representing approximately 10 per cent of the estimated total world gold production from skarns. Fifty-three per cent of the province's gold production from skarn deposits was won as a primary commodity, but virtually all of the silver was derived as a byproduct, largely from copper and iron mining operations.

Gold production from skarn in British Columbia has been predominantly from two world-class deposits, the Nickel Plate and Phoenix mines, which together were responsible for 82 per cent of the gold and 57 per cent of the silver produced from skarn. Gold was the primary product of the Nickel Plate deposit and a byproduct of copper production from the Phoenix deposit. It is the size and grade of these two deposits that make the exploration for other gold-bearing skarns in this province so potentially rewarding.

Precious metal enrichment occurs mostly in calcic skarns; PME magnesian skarns are exceedingly rare in British Columbia. Gold enrichment is most common in deposits having copper or iron-skarn affinities, and is less common in tungsten, zinc or lead skarns. The gold varies from very coarse, free and visible grains to micron-sized particles intimately associated with the sulphides.

PME skarn occurrences are evenly distributed within the Insular, Coast, Intermontane and Omineca tectonic belts but there are no known occurrences in the easternmost Foreland Belt. The majority (76 per cent) of the precious metal producing skarn mines are confined to the Insular and Omineca belts but over half of the total gold produced (53 per cent) has come from the Intermontane Belt which reflects production from the Hedley camp. By contrast, 98 per cent of the total silver production from skarn was derived from the Insular and Omineca belts; that from the Insular Belt was largely a byproduct of mining the iron skarns while most of the silver from the Omineca Belt was a byproduct from the Phoenix copper-skarn mining operation.

Although the 126 occurrences of PME skarn in the province are distributed within 14 different tectonic terranes (as defined by Wheeler *et al.*, 1988), the majority (78 per cent) are concentrated in the Quesnellia, Stikinia, Wrangellia and Alexander terranes. However, most of the precious metal-producing deposits (86 per cent) are confined to the Wrangellia and Quesnellia terranes which are dominated by island arc and back-arc basin assemblages and arc-related comagmatic intrusions. This apparent discrepancy between the distribution of the PME-skarn occurrences and producers may reflect poorer access in the Stikinia and Alexander terranes, suggesting they have good exploration potential.

There is a lithological control to PME skarns; more than 80 per cent of the occurrences are associated with deformed limestone or marble-rich sequences that often also contain some shale/argillite, conglomerate, tuff and volcanic flow components. There is also an apparent temporal control; over 60 per cent of the PME-skarn producers in British Columbia are hosted by Triassic rocks and 43 per cent are associated with Jurassic intrusions. This is probably because the most extensive island arc and back-arc basin assemblages favourable to PME skarn development largely comprise Triassic limy supracrustal rocks and Jurassic arc-related intrusions. These favourable assemblages include rocks of the Nicola, Rossland, Stuhini, Takla, Lewes River, Vancouver and Sicker groups, while further south, in the United States, they include rocks of the Wallowa, Old Ferry, Rattlesnake Creek, Jackson and Foothills terranes.

PME skarns are associated with intrusions that vary compositionally from granite to gabbro but are mainly found with rocks of quartz diorite to diorite composition. All those studied to date are associated with subalkalic, I-type intrusions that mostly possess calc-alkaline affinitites.

The calc-silicate mineral assemblages found in PME skarns are similar to those encountered in base and ferrous metal skarns and thus cannot be used to distinguish mineralization with precious metal potential. Likewise, the degree of retrograde alteration overprinting the prograde garnet-pyroxene assemblages varies considerably in PME skarns and cannot be used as an exploration guide. However, PME skarns tend to be rich in pyroxene relative to garnet, and mineralogical zoning patterns manifest as garnet-dominant proximal zones and pyroxene-dominant distal zones are recognized in many skarn envelopes. The sulphide-rich precious metal mineralization is rarely developed in the endoskarn but is generally hosted by pyroxene-rich exoskarn in the outer portions of the skarn envelope.

Most PME skarns have iron or copper-skarn affinities and are associated with pyroxenes and grandite garnets that have a very low manganese content (<0.5 per cent MnO); the notable exceptions are the Tillicum Mountain gold and silver skarns which may have lead-zinc-skarn affinities and contain pyralspite garnets with up to 23 per cent MnO. Some garnets and pyroxenes in PME skarns are characterized by very narrow aluminous growth zones. Depending on the iron content of the pyroxenes, the sporadic presence of Al_2O_3 + TiO_2 values greater than 1.25 weight per cent may indicate a high

precious metal potential, although the presence of pyroxenes with values less than 1.25 weight per cent does not necessarily rule out the gold potential of a skarn. Skarns with pyroxenes containing greater than 26.0 and less than 3.5 weight per cent FeO are believed to indicate a low precious metal potential.

Pyrrhotite, pyrite, arsenopyrite, chalcopyrite, bornite, sphalerite and cobaltite are the commonest sulphides in most PME skarns. Those enriched in gold are often characterized by arsenopyrite, hedleyite, bismuthinite, native bismuth, maldonite and cobaltite, while in the silver-dominant skarns galena and sphalerite are more abundant. There is a highly variable metallic trace element assemblage in PME skarns which may be enriched in Au, Ag, Cu, Zn, As, Co, Bi, Te, W, Sb and rarely Mo. The presence of bismuth and/or tellurium in a skarn is regarded as indicative of high precious metal potential.

In some skarn camps, such as Hedley and Texada Island, there are suggestions that the skarn deposits are metallogenically zoned on a district scale. This zoning may include district-wide changes from iron to copper-gold skarns, copper to gold skarns or tungsten-copper to gold skarns; this may also be accompanied by broad zoning patterns in other trace elements.

PME skarns cannot be classified adequately using the criteria used to classify base and ferrous metal skarns. However plotting Cu:Ag versus Cu:Au ratios of a mineralized skarn will broadly differentiate gold, copper and iron skarns, as well as a group of silver-rich, gold-poor skarns that commonly contain abundant lead and/or zinc. Generally, the Cu:Au ratios are less than 1000 in gold skarns, between 2000 and 25 000 in copper skarns and between 20 000 and 160 000 in iron skarns.

The amount of skarn alteration associated with precious metal mineralization may vary from narrow envelopes, less than 10 metres wide, to extensive zones hundreds of metres thick and covering several square kilometres in area. The total amount of gold in the system may be proportional to the amount of skarn alteration; thus, larger tonnage precious metal deposits are more likely to be found in areas characterized by extensive alteration envelopes.

This study suggests that British Columbia has excellent potential for new discoveries of economic PME-skarn deposits similar to those in the Hedley, Greenwood, Texada Island and Tillicum Mountain camps. The most prospective regions lie within either the Quesnellia, Wrangellia, Alexander or Stikinia terranes, particularly in areas adjacent to, or overlying the margins of fracture-controlled, island-arc or back-arc basins that contain Late Triassic to Early Jurassic limy supracrustal rocks and varied suites of subalkalic, calc-alkaline, arc-related intrusions of Jurassic to Cretaceous age. Areas with ferrous or base metal skarns, porphyry copper mineralization or arsenic, bismuth, tellurium or cobalt geochemical enrichment are regarded as being particularly favourable for economic PME-skarn deposits. However, it is emphasized that skarns of any type should be routinely checked for precious metals by explorationists.

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CHAPTER 1

INTRODUCTION

Despite the well-documented 60-year history of major gold production from the world-class Nickel Plate mine in British Columbia (Camsell, 1910; Billingsley and Hume, 1941), precious metal enriched (PME) skarns have only recently been widely recognized as a distinct class of skarn deposit (Meinert, 1987a; Orris *et al.*, 1987). Recent discoveries of major PME-skarn deposits in Nevada, U.S.A. (Theodore *et al.*, 1986; Wotruba *et al.*, 1986; Kuyper, 1987), Australia (Torrey *et al.*, 1986) and elsewhere, as well as the reopening of the Nickel Plate mine in 1987 as an open-pit operation (Simpson and Ray, 1986; Ray *et al.*, 1987, 1988), have caused considerable excitement and a realization that PME skarns represent exploration targets with both high grade and large tonnage potential (Table 1). Yet, despite their economic importance, there is general uncertainty regarding their geological controls, physiochemical conditions of formation, classification, and relationship to the base and ferrous metal skarns.

This paper is the result of studies that involved geological mapping in some selected skarn camps, extensive literature research and various laboratory studies; the latter included whole-rock and trace element analyses, petrographic examination of sulphide and calc-silicate assemblages, and electron microprobe analyses of various garnet and pyroxene mineral phases associated with the skarn alteration. Preliminary reports on these studies have been published by Ray and Dawson (1987, 1988), Ray *et al.* (1987, 1988) and Ettlinger and Ray (1988).

The purpose of this paper is to present relevant data on the proven and potential PME skarns in British Columbia and outline their various characteristics, including distribution, mineralogy, geochemistry, geological controls and classification. We believe these data and our conclusions will stimulate further studies and aid exploration for new economic PME-skarn deposits in the Cordillera.

Skarn deposits worldwide have produced more than 1000 tonnes of gold (Meinert, 1987a), and the skarns of British Columbia have contributed nearly 10 per cent of this production. Between 1858 and 1984, "lode" deposits in British Columbia produced approximately 615.2 tonnes of gold (Schroeter and Panteleyev, 1986) of which PME skarns contributed 15.5 per cent, or 95.4 tonnes

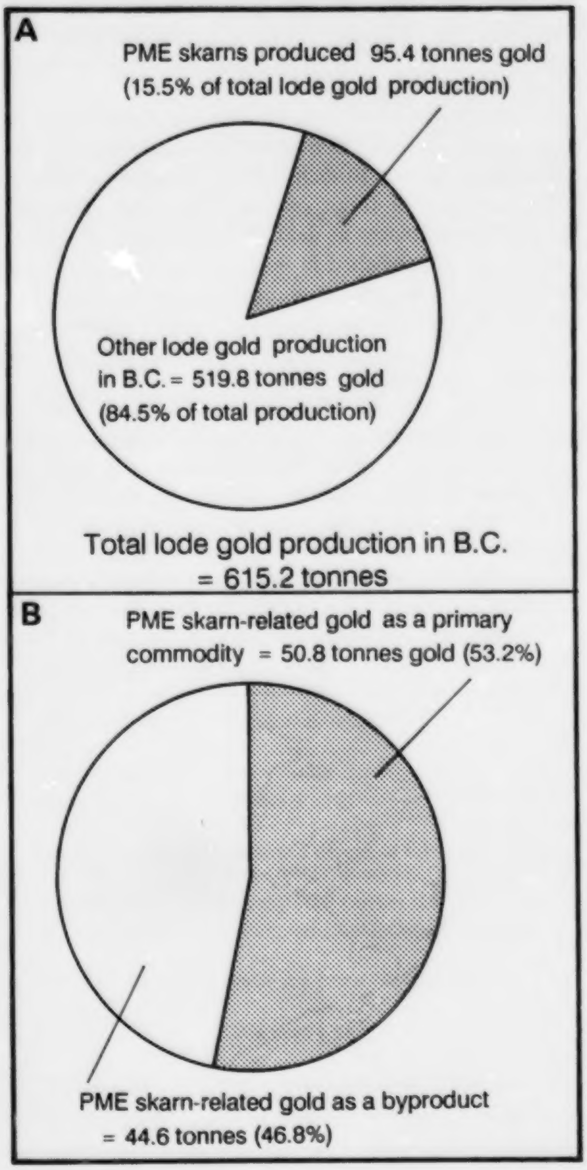

Figure 1A. Gold production from skarn compared to total lode gold production in British Columbia between 1858 and 1984. (Lode gold data after Schroeter and Panteleyev, 1986.) Figure 1B. Percentages of byproduct and primary product gold derived from PME skarns in British Columbia.

(Figure 1A; Table 2). Of this skarn-related gold production, 53 per cent was won as a primary commodity and approximately 47 per cent was derived as a byproduct from base or ferrous metal mining (Figure 1B).

The worldwide distribution of some PME-skarn deposits is shown in Figure 2 and the available data concerning the size and grades of some of these deposits are listed in Table 1. Although many deposits in the U.S.S.R. and China are not included in the figure, it is apparent that PME skarns tend to be concentrated in the younger, tectonically active mobile belts, and are rarely developed in Proterozoic or Archean rocks.

In British Columbia more than 350 skarn occurrences or deposits have been identified and are listed in the Geological Survey Branch MINFILE database (1987). The majority of these contain skarn-type alteration mineral assemblages as defined by Einaudi *et al.* (1981) and some are enriched in iron, copper, tungsten, lead, zinc, tin, molybedenum and precious metals. They range in size and importance from small outcrop occurrences to larger deposits that are past or current producers of ferrous, base and/or precious metals.

Of the 350 skarn occurrences, at least 126 are regarded as PME skarns as they reportedly contain anomalous values of gold and/or silver; two of these occurrences are also enriched in platinum. Each of these 126 PME skarns, which comprise one or more British Columbia MINFILE occurrences, are listed in Appendix 1, together with data concerning ore production (where applicable), skarn mineralogy, associated metallic trace elements, and the types and ages of the host and associated intrusive rocks. However, since the quality of the reported grade and production data is variable from occurrence to occurrence, it is not possible to present an overall definition of "PME skarn" based on precise precious metal grades. Consequently, the occurrences listed in Appendix 1 have been categorized as PME skarns because they either produced some gold and/or silver, contained visible gold, or anomalous gold or silver values have been reported. For several reasons, including the high density of PME-skarns in some districts, it was only possible to plot 74 PME-skarn localitites on the map presented in Figure 3 (in pocket) and these are referred to in column 1 of Appendix 1. Of the 126 PME-skarn occurrences, 49 have reported some gold and/or silver production (Table 2).

PRODUCTION AND DISTRIBUTION OF PME SKARNS

Skarn deposits in British Columbia have produced 95.4 tonnes of gold and 342 tonnes of silver (Table 2). The relative proportions of gold derived from the three most productive PME-skarn camps in the province are shown in Figure 4A; this illustrates the dominance of the Hedley and Greenwood camps, which together were responsible for over 90 per cent of the province's skarn-derived gold production. The importance of these camps is due to their containing two world-class deposits (Figure 4B), the Nickel Plate gold mine in the Hedley camp, which represents a primary commodity gold skarn, and the Phoenix copper mine in the Greenwood camp, which represents a gold-enriched copper skarn with substantial byproduct gold and silver production. If these two deposits had not

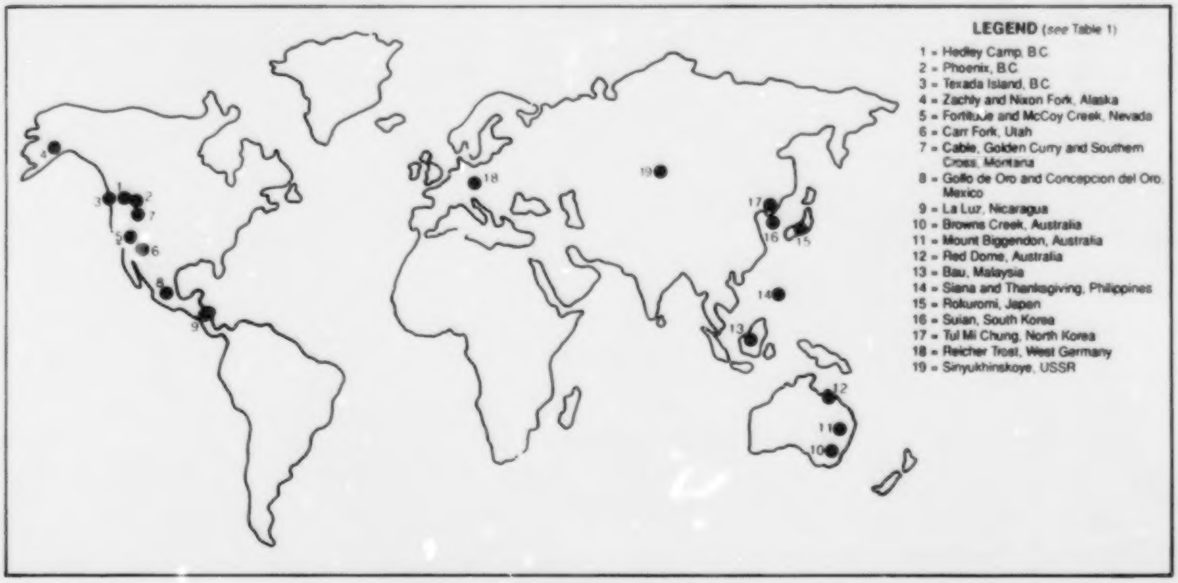
LEGEND (see Table 1)
1 = Hedley Camp, B.C.
2 = Phoenix, B.C.
3 = Texada Island, B.C.
4 = Zachly and Nixon Fork, Alaska
5 = Fortitude and McCoy Creek, Nevada
6 = Carr Fork, Utah
7 = Cable, Golden Curry and Southern Cross, Montana
8 = Gollo de Oro and Concepcion del Oro, Mexico
9 = La Luz, Nicaragua
10 = Browns Creek, Australia
11 = Mount Biggendon, Australia
12 = Red Dome, Australia
13 = Bau, Malaysia
14 = Siana and Thanksgiving, Philippines
15 = Rokuromi, Japan
16 = Suian, South Korea
17 = Tul Mi Chung, North Korea
18 = Reicher Trost, West Germany
19 = Sinyukhinskoye, USSR
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Figure 2. Selected PME skarns of the world.

TABLE 1
SELECTED PME-SKARNS OF THE WORLD (*see* Figure 2)

NO. IN FIG. 2	DEPOSIT	SIZE (tonnes)	Au (g/t)	Ag (g/t)	Cu (%)	REFERENCES
1	Nickel Plate and Hedley-Mascot, B.C. (underground)	3 600 000	14.0	1.4	0.1	National Mineral Inventory; Simpson (1986); Ray *et al.* (1987)
1	Nickel Plate-Hedley, B.C. (open pit)	8 900 000*	4.5*	3.0**	0.1	Mascot Gold Mines Ltd. report, Nov. 1987
2	Phoenix, B.C.	26 956 000	1.1	7.1	0.9	Peatfield (1978); Church (1986)
3	Texada Island, B.C. (Cu-Au skarns)	310 000	2.4	16.0	3.0	Peatfield (1987)
4	Zackly, Alaska	1 200 000	5.5	30.0	2.7	Meinert (1987a)
4	Nixon Fork, Alaska	NA	NA	NA	NA	
5	Fortitude, Nevada	10 300 000	6.9	24.7	0.1	Blake *et al.* (1984); Wotruba *et al.* (1986)
5	McCoy Creek, Nevada	8 700 000	1.9	NA	0.1	Tingley and Smith (1982); Lane (1987)
6	Carr Fork, Utah	61 000 000	0.4	10.7	1.8	Cameron and Garmoe (1983)
7	Cable, Montana	1 000 000	6.0	5.0	3.0	Holser (1950); Earll (1972)
7	Golden Curry, Montana	930 000	8.5	4.2	0.33	Roby *et al.* (1960); Orris *et al.* (1987)
7	Southern Cross, Montana	400 000	13.0	16.0	0.1	Emmons and Calkins (1913); Earll (1972) Orris *et al.* (1987)
8	Golfo de Oro, Mexico	5 000 000	4.5	10.0	NA	Orris *et al.* (1987)
8	Concepcion del Oro, Mexico	15 000 000	1.7	NA	2.0	Buseck (1966); Einaudi *et al.* (1981)
9	La Luz, Nicaragua	16 000 000	4.1	1.2	0.44	Sillitoe (1983); Orris *et al.* (1987)
10	Browns Creek, Australia	740 000	7.5	9.0	0.4	Taylor (1983); Meinert (1987a)
11	Mount Biggendon, Australia	500 000	15.0	NA	NA	Clarke (1969)
12	Red Dome, Australia	13 800 000	2.0	4.6	0.46	Torrey *et al.* (1986)
13	Bau, Malaysia	2 400 000	7.2	0.1	NA	Boyle (1979); Bowles (1984)
14	Siana, Philippines	5 400 000	5.1	10.0	NA	Orris *et al.* (1987)
14	Thanksgiving, Philippines	1 700 000	6.4	40.6	0.4	Philippine Bureau of Mines and Geosciences(1986); quoted in Orris *et al.* (1987)
15	Rokuromi, Japan	160 000	4.1	1.0	NA	Grant (1950); Orris *et al.* (1987)
16	Suian, South Korea	530 000	13.0	4.9	NA	Elevatorski (1981); Orris *et al.* (1987)
17	Tul Mi Chung, North Korea	400 000	12.0	NA	NA	Watanabe (1943); Gallagher (1963)
18	Reicher Trost, West Germany	< 10 000	20.0	0.1	NA	Orris *et al.* (1987)
19	Sinyukhinskoye, USSR	NA	NA	NA	NA	Grab sample collected by Ettlinger, 1988
***	Salsione, France	1 500 000	13	33	0.15	Elevatorski (1981); Meinert (1987a)

NA = values not available.

*Recently downgraded to 8 250 000 tonnes grading 3.02 g/t Au (Corona Corporation announcement, Dec. 1988).

**Estimated silver grade.

***Not shown in Figure 2.

TABLE 2
GOLD AND SILVER PRODUCTION FROM 49 PME SKARN DEPOSITS IN BRITISH COLUMBIA
(Listed in order of gold production)

DEPOSIT	GOLD PRODUCTION (kg)	SILVER PRODUCTION (kg)	BELT	TERRANE
Nickel Plate	41705.00	4160.00	IMT	QEN
Phoenix	30225.00	192055.00	OMN	QEN
Mascot Fraction	6937.00	1707.00	IMT	QEN
Motherlode	5391.00	21406.00	OMN	QEN
Old Sport	3869.00	11731.00	INS	WR
Marble Bay	1544.00	12621.00	INS	WR
French	1362.00	181.00	IMT	QEN
Tasu	1340.00	50394.00	INS	WR
Texada Iron	888.00	23644.00	INS	WR
Dividend-Lakeview	504.00	88.00	IMT	QEN
Cornell	471.00	2194.00	INS	WR
Little Billie	363.00	1198.00	INS	WR
Emma (Bluebell)	212.00	2434.00	OMN	QEN
Good Hope	178.00	120.00	IMT	QEN
Oro Denoro	117.00	954.00	OMN	QEN
Heino-Money	107.00	103.00	OMN	QEN
Lily Mine	51.19	862.54	INS	WR
Copper Queen	47.00	355.00	INS	WR
Jackpot	31.41	8500.00	OMN	ANA
Dewdney	22.45	1707.00	INS	WR
Canty	16.00	NR	IMT	QEN
Greyhound	16.00	349.00	OMN	QEN
Marshall	15.00	18.00	OMN	QEN
Morrison	8.00	26.00	OMN	QEN
Orinoco	7.65	950.01	OMN	QEN
Silverado	5.56	10.29	INS	WR
Beano	3.29	1.4	INS	WR
Mormon Girl	3.29	9.64	OMN	ANA
Loyal Canadian	0.90	4.41	OMN	QEN
Morning	0.87	0.74	INS	WR
Molly B	0.68	3.48	CC	ST
Rely	0.56	4.97	OMN	QEN
Cambrian Chief	0.52	125.00	CC	WR
Sunnyside	0.37	81.64	OMN	QEN
Maid of Erin	0.34	1500.00	INS	AX
Blue Grouse	0.21	2509.00	INS	WR
Lucky Mike	0.06	4.26	IMT	QEN
Gribble Island	0.03	1.30	CC	UM
Geo (Star of the West)	0.03	NR	INS	WR
Contact	0.00	10.45	OMN	CA
East Copper Isl	0.00	0.71	INS	WR
Hab Bob	0.00	41.14	INS	WR
Roadside	0.00	6.22	CC	WR
Sir Douglas Haig	0.00	0.18	OMN	QEN
Salmo-Malarctic	0.00	36.35	OMN	ANA
Merry Widow (a)	NR	NR	INS	WR
Peggy (b)	NR	NR	IMT	QEN
Elk (c)	NR	NR	OMN	QEN
Silver Queen (d)	NR	NR	OMN	QEN
TOTAL PRODUCTION (kg)	**95444.41**	**342108.73**		

(a) 1683507 t of iron concentrate produced. Some silver byproduct reported.

(b) Limited but unknown gold production.

(c) 154 t of silver-rich ore produced.

(d) Limited but unknown silver production.

NR = Not Reported.

HOSTING BELTS

INS = Insular
CC = Coast
IMT = Intermontane
OMN = Omineca

HOSTING TERRANES

WR = Wrangellia
AX = Alexander
CA = Cassiar
UM = Undifferentiated metamorphics
ST = Stikinia
QEN = Quesnellia
ANA = Ancestral North America

been found, skarns in British Columbia would probably not be regarded as significant targets for gold exploration. However, it is the size and grade of the Nickel Plate and Phoenix deposits which makes the search for other PME-skarn deposits in this province so potentially rewarding.

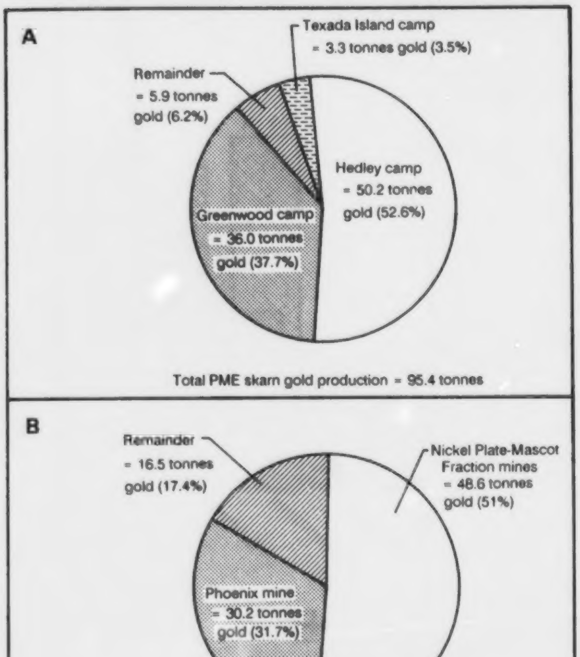


Figure 4. Production of gold from (A): the Hedley, Greenwood and Texada Island PME skarn camps compared to total PME skarn production. (B): the Nickel Plate and Phoenix mines compared to total PME skarn production. (C): production of silver from eight major skarn deposits compared to total PME skarn silver production.

Silver production from nine of British Columbia's most productive skarns is illustrated in Figure 4C. In contrast to gold, the largest skarn-derived silver production is from the Phoenix mine, and the small amount of silver won from the Nickel Plate deposit is overshadowed by the much larger production from the iron and copper skarn deposits at the Tasu, Texada Iron and Old Sport mines. It is apparent that most gold production has been from gold and copper skarns, while silver is predominantly derived from copper and iron skarns.

DISTRIBUTION BY TECTONIC BELT

The distribution of PME-skarn occurrences in relation to the five tectonic belts is shown in Figure 5A. The four western, more plutonically active and mobile belts each contain approximately the same number of occurrences, but no PME skarns are reported in the eastern, more stable Foreland Belt. Despite the similar number of occurrences in the Insular, Coast, Intermontane and Omineca belts, the distribution of the 49 PME-skarn producers (Figure 5B) listed in Table 2, and the amount of gold and silver produced (Figures 6A and 6B) varies considerably from belt to belt. Over 90 per cent of the gold production comes from the Intermontane and Omineca belts which largely reflects the major production from the Hedley and Greenwood camps, respectively. The Insular Belt hosts 37 per cent of the producers, but is only responsible for 9 per cent of the total gold production, while the Intermontane Belt with only 16 per cent of the producers accounts for 53 per cent of total gold production. This reflects the fact that most gold produced in the Insular Belt was derived as a byproduct from the numerous iron and copper-skarn deposits characterized by low gold values, whereas the Intermontane Belt has less numerous, but higher grade gold-bearing skarns where gold is the primary product. Although the Coast Belt contains 24 per cent of the PME-skarn occurrences (Figure 5A) and 8 per cent of the producers (Figure 5B), it has produced only 0.001 per cent of the total skarn-derived gold (Figure 6A). This is probably due to the lack of major carbonate assemblages in the Coast Belt, and because most of the Coast Range plutonic rocks do not have comagmatic, island-arc or back-arc affinities.

Over 98 per cent of skarn-related silver production came from the Omineca and Insular belts (Figure 6B). The predominance of the Omineca belt is due to production from the Phoenix deposit, while the high silver production from the Insular Belt reflects the abundance of the silver-rich iron skarns such as the Tasu and Texada Island deposits.

It is noteworthy that most gold production has come from the Intermontane Belt (Figure 6A) while the most silver was produced from the Omineca Belt (Figure 6B). This perhaps reflects the predominantly oceanic, vol-

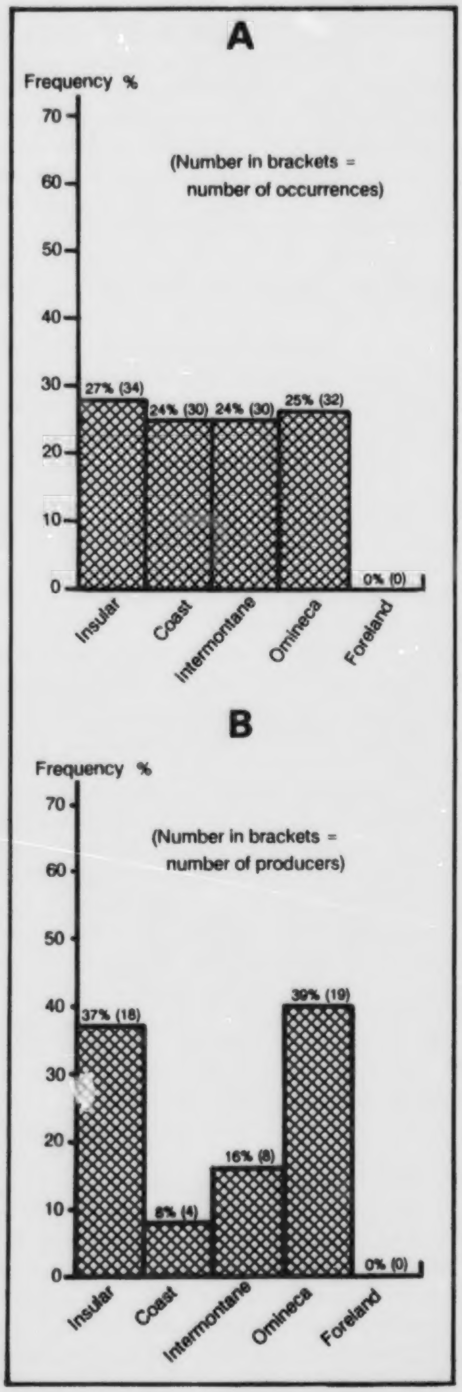


Figure 5A. Distribution of PME skarn occurrences listed in Appendix 1 by tectonic belt. Figure 5B. Distribution of the 49 PME skarn producers listed in Table 2 by tectonic belt.

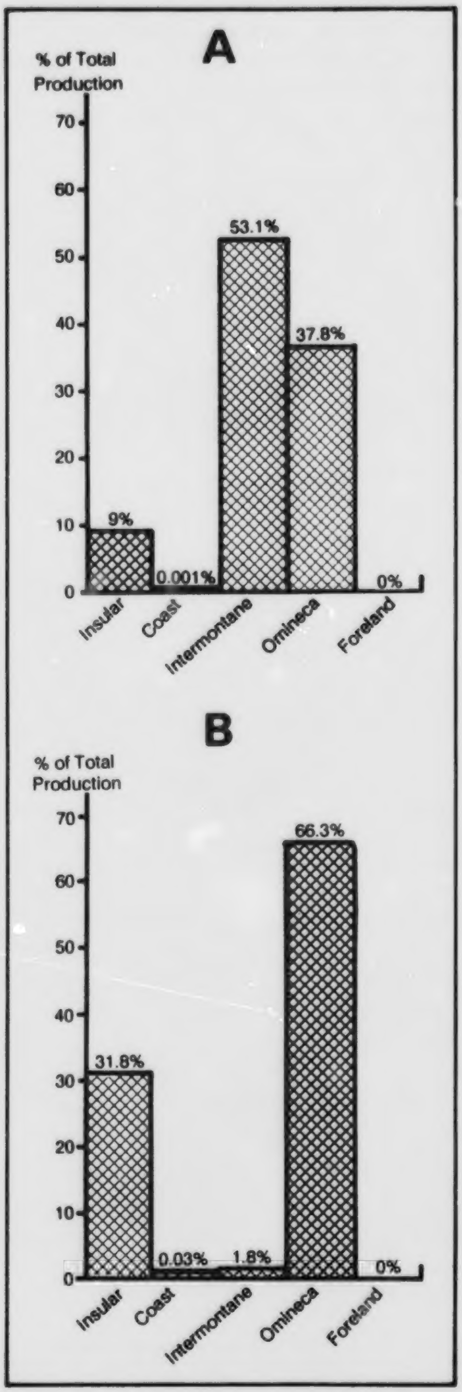


Figure 6. Percentage of (A): PME skarn gold production by tectonic belt. (Total gold production = 95.4 tonnes.) (B): PME skarn silver production by tectonic belt. (Total silver production = 342 tonnes.)

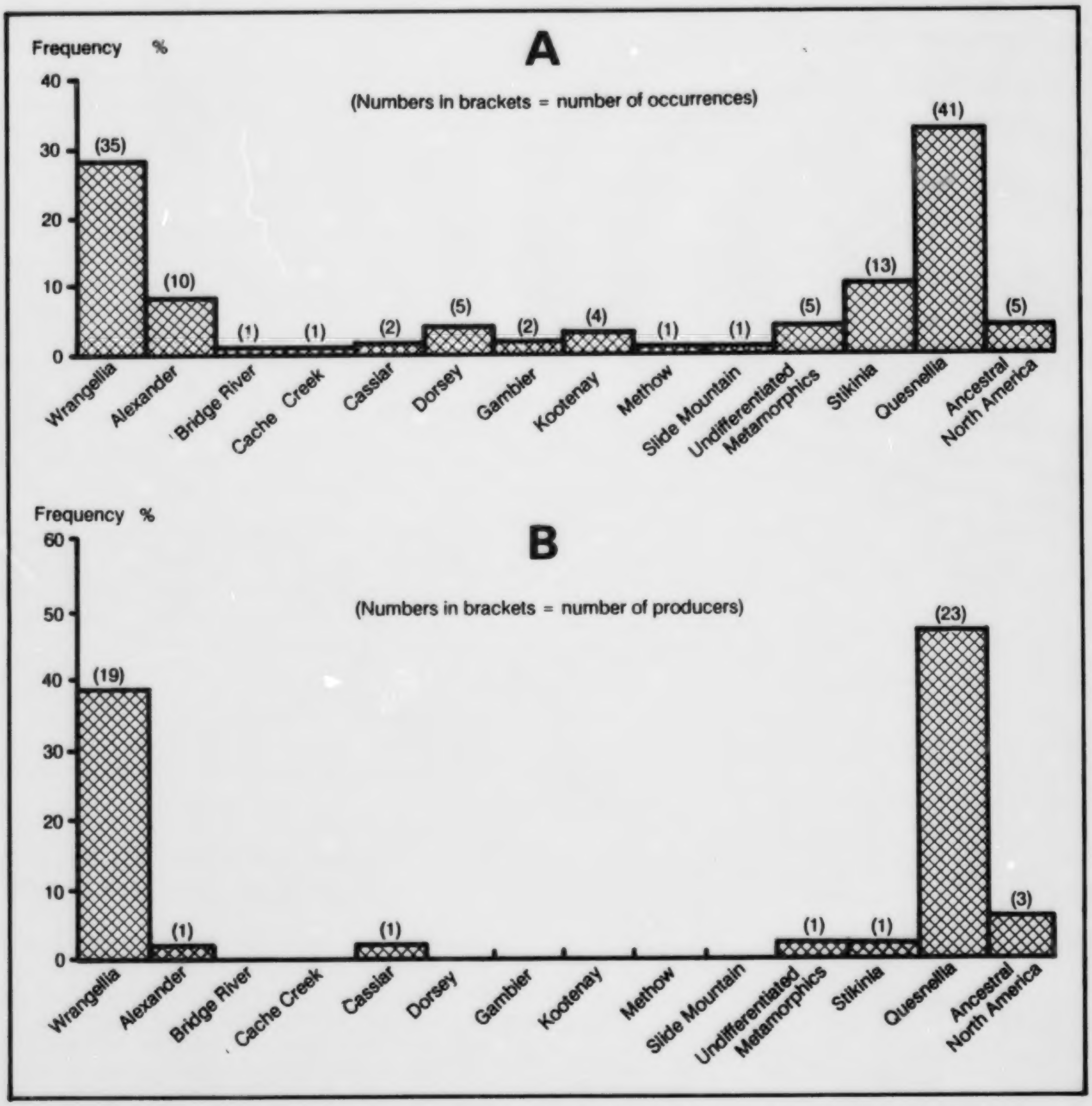


Figure 7. Distribution of (A): the 126 PME skarn occurrences listed in Appendix 1 by tectonic terrane; (B): the 49 PME skarn producing mines listed in Table 2 by tectonic terrane.

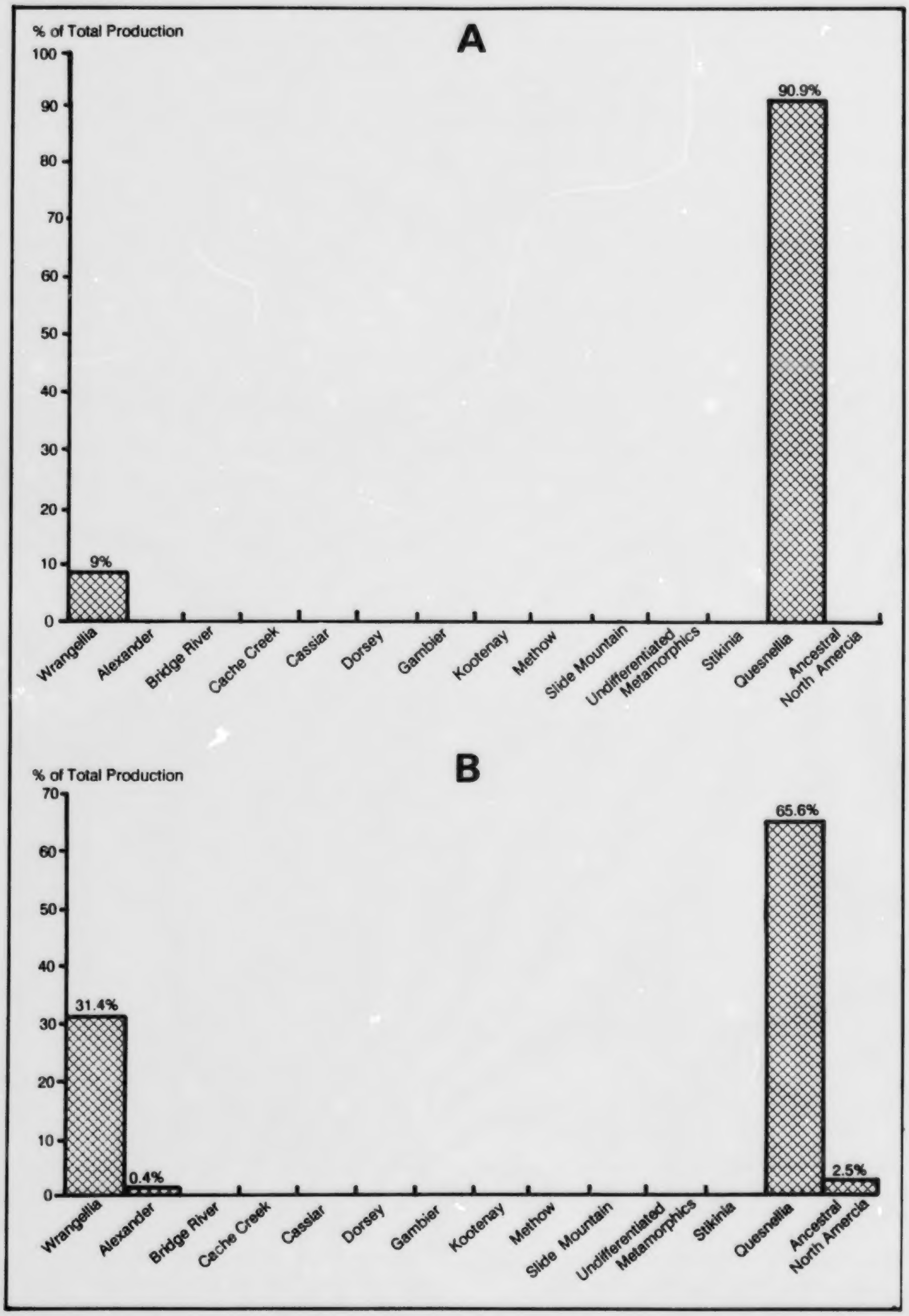


Figure 8. Percentages of (A): gold production from PME skarns by tectonic terrane. (B): silver production from PME skarns by tectonic terrane.

canic-arc character of the Intermontane Belt which favours gold mineralization and the more sialic, continental character of the Omineca Belt which typically favours silver together with lead-zinc mineralization.

DISTRIBUTION BY TECTONIC TERRANE

The PME skarns listed in Appendix 1 occur within 14 tectonic terranes as defined by Wheeler *et al.* (1988) (Figure 7A). However, over 60 per cent of the occurrences are confined to Wrangellia and Quesnellia, and a further 18 per cent are concentrated in Alexander and Stikinia. The remaining 21 per cent are widely distributed in 10 other terranes. Precious metal production from skarn deposits is limited to only seven of these terranes (Figure 7B); Wrangellia and Quesnellia again stand out in together containing 86 per cent of the producers. Likewise, these two terranes dominate skarn-related gold and silver production (Figures 8A and 8B). Over 90 per cent of the gold and 65 per cent of the silver produced has originated from PME skarns in Quesnellia which again reflects production from the Hedley and Greenwood camps. The high silver production (31 per cent of total) from Wrangellia is due to the silver-rich iron skarn deposits in that terrane.

To summarize, PME-skarn occurrences in British Columbia are mainly concentrated in the accreted Quesnellia, Wrangellia, Stikinia and Alexander terranes, which are characterized, in part, by volcanic island arc and back-arc basin volcanics, associated clastic sediment and comagmatic calc-alkaline plutons that were intruded during the waning stages of arc development. Gold and silver production however has come overwhelmingly from Quesnellia and Wrangellia, and virtually none has been won from skarns in the Stikinia or Alexander terranes.

LITHOLOGICAL AND TEMPORAL CONTROLS OF PME SKARNS

The frequency distribution of hostrock lithologies associated with the 126 PME-skarn occurrences listed in Appendix 1, as reported in the literature and unpublished assessment reports, is shown in Figure 9. More than one host lithology is recorded for many occurrences and consequently the distribution in Figure 9 does not total 100 per cent. Although carbonate is not essential for local skarn development, 84 per cent of the skarn occurrences reportedly have marble or limestone present in the immediate area, but dolostone is described at only 3 per cent of the occurrences. Other skarn host lithologies, in decreasing order of importance are shale/argillite (32 per cent), tuff (23 per cent), volcanic flows of various compositions (21 per cent), gneiss and/or schist (21 per cent) and quartzite (20 per cent).

The most extensive island arc and back-arc basin assemblages in British Columbia favourable to PME-skarn development are Late Triassic to Early Jurassic in age. This explains the apparent temporal control to mineralization; over 60 per cent of the producing deposits are hosted in Triassic rocks (Figure 10A) and 43 per cent are associated with intrusions of Jurassic age (Figure 10B). Over 8 per cent of the producing deposits occur in Cambrian rocks (Figure 10A) which reflects the prevalence of carbonates in some Cambrian successions.

Favourable Late Triassic to Early Jurassic arc sequences in British Columbia include rocks of the Nicola, Rossland, Stuhini, Takla, Vancouver and Sicker groups. Similar Late Triassic subduction-related assemblages occur further south in the United States. These include rocks of the Wallowa, Old Ferry, Rattlesnake Creek, Jackson and Foothills terranes (Mortimer, 1986) which therefore also have good PME skarn potential.

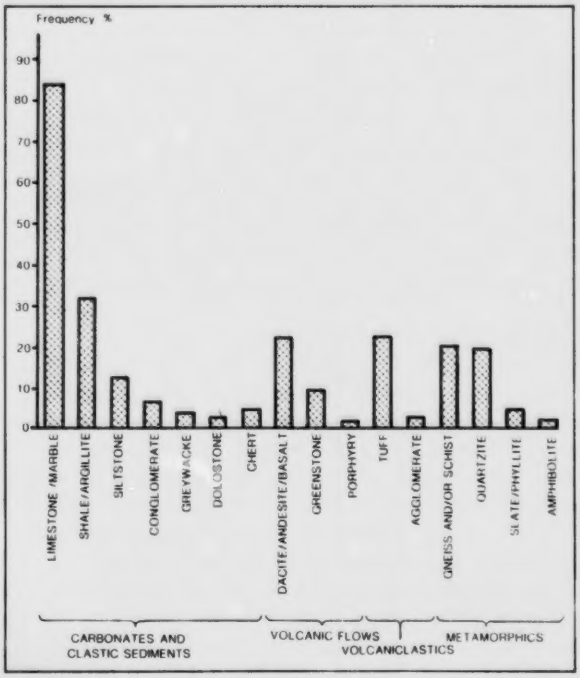


Figure 9. Frequency of hostrock lithologies reportedly present at the PME-skarn occurrences listed in Appendix 1. (Note: more than one lithology is reported for some occurrences.)

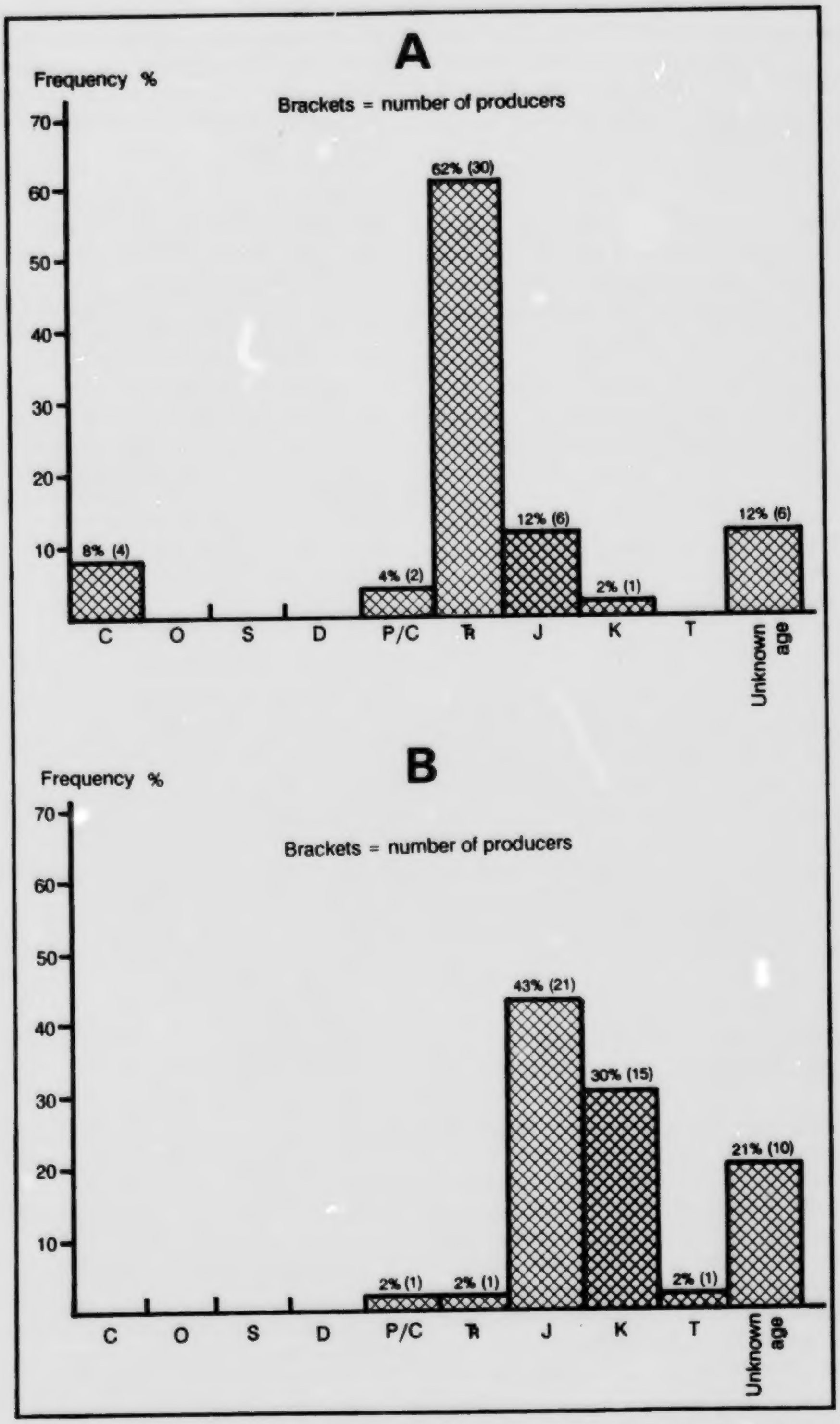


Figure 10. Distribution of the 49 PME-skarn producing mines listed in Table 2 relative to (A): age of the host rocks, (B): age of the related intrusive rocks.

CHAPTER 2

GEOLOGY OF SELECTED PME SKARNS IN THE INTERMONTANE BELT

HEDLEY CAMP

The Hedley camp, situated approximately 40 kilometres east-southeast of Princeton in southern British Columbia, is the largest and economically most important PME-skarn district in the province. It has had a long history of intermittent gold mining (Camsell, 1910; Billingsley and Hume, 1941; Dolmage and Brown, 1945; Simpson, 1986, 1987, 1988) and between 1902 and 1955 approximately 51 million grams of gold were won from at least four gold-bearing skarn deposits. More than 95 per cent of the gold production in the camp came from one very large deposit which was worked at the Nickel Plate and Hedley Mascot mines. Smaller amounts of gold were recovered from the French, Goodhope and Canty auriferous skarn deposits. In addition to these deposits, there are numerous small gold-bearing skarn occurrences in the Hedley district, including the Peggy which has had some underground work but no reported production. In the eastern part of the Hedley district, at Mount Riordan, there is also a large tungsten-copper-bearing skarn which contains some silver but only very low gold values (Ray *et al.*, 1988). Exploration interest in the Hedley gold camp has been revitalized by the recent reopening of the Nickel Plate mine by Mascot Gold Mines Limited (now Corona Corporation) as a 2450 tonne per day open-pit operation.

The gold-bearing skarn mineralization is hosted in Upper Triassic Nicola Group rocks and is genetically related to a suite of subalkalic, calc-alkaline dioritic intrusions of Early Jurassic age. A series of facies changes recognized within the Nicola succession is related to deposition across a fracture-controlled basin margin; it is economically important as the gold mineralization in the Hedley district is lithologically, stratigraphically and structurally controlled.

A district-wide metallogenic zoning may exist in the Hedley camp with gold and arsenic-rich skarns developed to the west and tungsten-rich, gold and arsenic-poor skarns to the east. This type of zoning may have exploration significance elsewhere in the North American Cordillera.

GENERAL GEOLOGY

The Hedley camp lies within the Intermontane Belt of the Canadian Cordillera and the geology of the district is presented in Figure 11. The geology has been described by Camsell (1910), Bostock (1930, 1940a, 1940b) and more recently by Ray *et al.* (1986b, 1987, 1988), Simpson and Ray (1986), Ray and Dawson (1987, 1988), and Ettlinger and Ray (1988).

Most of the area is underlain by the Upper Triassic Nicola Group which contains three distinct stratigraphic packages. The oldest, the Peachland Creek formation largely comprises mafic tuffs and minor conglomerate; while the youngest, the Whistle Creek formation is essentially an andesitic to basaltic volcaniclastic sequence. Between these two formations is a predominantly sedimentary succession that hosts most of the gold-bearing skarns in the camp. Several east-to-west facies changes are recognized in this sequence, which progressively thickens from 100 metres in the east to over 700 metres in the west (Figure 12). These facies changes probably reflect deposition across the tectonically controlled margin of a Late Triassic marine basin which deepened to the west.

The easternmost and most proximal facies, the French Mine formation (Figures 11 and 12), has a maximum thickness of 150 metres and comprises massive to bedded limestone interlayered with thinner units of calcareous siltstone, chert-pebble conglomerate, tuff, limestone-boulder conglomerate and limestone breccia. It hosts the auriferous skarn mineralization at the French and Goodhope mines (Figure 12).

Further west, rocks stratigraphically equivalent to the French Mine formation are represented by the Hedley formation which hosts the gold-bearing skarn at the Nickel Plate mine. The Hedley formation is 400 to 500 metres thick and characterized by thinly bedded, turbiditic calcareous siltstones that display some soft sediment structures, and units of pure to gritty, massive to bedded limestone that reach 75 metres in thickness and several kilometres in strike length.

The most distal facies to the west is represented by the Stemwinder Mountain formation (Figures 11 and 12) which is at least 700 metres thick and characterized by a

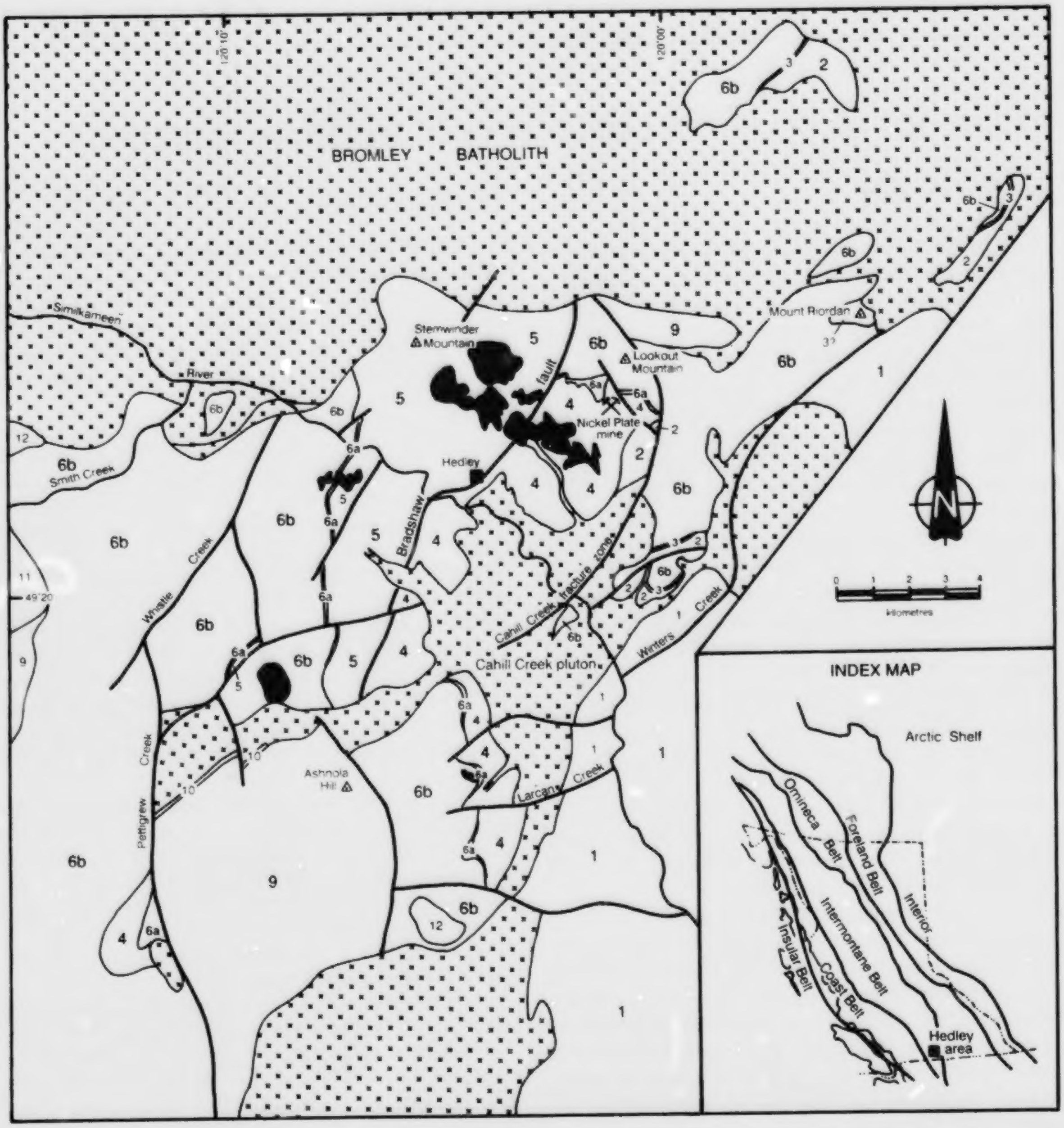

120°10'
120°00'
BROMLEY BATHOLITH
Similkameen
River
Stemwinder Mountain
Lookout Mountain
Mount Riordan
Nickel Plate mine
Hedley
fault
Bradshaw
Cahill Creek fracture zone
Cahill Creek pluton
Winters Creek
Whistle Creek
Smith Creek
Pettigrew Creek
Larcan Creek
Ashnola Hill
49°20'
1
2
3
3?
4
5
6a
6b
9
10
11
12
0 1 2 3 4
Kilometres
INDEX MAP
Arctic Shelf
Omineca Belt
Foreland Belt
Interior
Intermontane Belt
Insular Belt
Coast Belt
Hedley area

Figure 11. Regional geology of the Hedley district, southern British Columbia (after Ray *et al.*, 1988). (For legend *see* page 21.)

LEGEND

TERTIARY

12	Basaltic flows

EROSIONAL UNCONFORMITY

EARLY CRETACEOUS

11	VERDE CREEK INTRUSION – *granite and microgranite*
10	RHYOLITE INTRUSION – *quartz porphyry*
9	SPENCES BRIDGE GROUP – *andesitic to dacitic pyroclastics and flows with minor sediments*

CONTACT UNCERTAIN

EARLY JURASSIC

8	BROMLEY BATHOLITH AND CAHILL CREEK PLUTON – *granodiorite to quartz monzodiorite*
7	HEDLEY INTRUSION – *quartz diorite, diorite, and gabbro*

INTRUSIVE CONTACT

NICOLA GROUP

LATE TRIASSIC

6b	WHISTLE CREEK FORMATION – *bedded to massive ash and lapilli tuff, minor tuffaceous siltstone*
6a	Copperfield Conglomerate – *limestone boulder conglomerate*
5	STEMWINDER MOUNTAIN FORMATION (WESTERN FACIES) – *thinly bedded argillite and limestone*
4	HEDLEY FORMATION (CENTRAL FACIES) – *thinly bedded siltstone, thick limestone beds and minor tuffs*
3	FRENCH MINE FORMATION (EASTERN FACIES) – *limestone, limestone breccia and pebble conglomerate*
2	PEACHLAND CREEK FORMATION – *basaltic ash tuffs and flows with minor limestone and chert-pebble conglomerate*

CONTACT OCCUPIED BY CAHILL CREEK PLUTON

PALEOZOIC

1	APEX MOUNTAIN COMPLEX – *ophiolite sequence of cherts, greenstones, siltstones, argillites and minor limestones*

monotonous sequence of black, organic-rich, thinly bedded calcareous argillite and turbiditic siltstone, and dark impure limestone beds that seldom exceed 3 metres in thickness.

Conodonts of late Carnian to late Norian age were obtained from limestones in the Hedley and Stemwinder Mountain formations (M.J. Orchard, personal communications, 1985, 1986; Ray and Dawson, 1987). Paleocurrent measurements suggest that the rocks in the Stemwinder, Hedley and Whistle Creek formations were derived from an easterly source. The French Mine formation was laid down in a proximal, shallow, possibly forereef marine environment that received deposition of angular limestone breccias and chert-pebble conglomerates. Deposition of the more distal Hedley formation involved slower, more turbiditic sedimentation with the occasional influx of coarser conglomerate, tuff and coarse gritty limestone. The limestones and calcareous siltstones are characterized by a general absence of both bioturbation and shelly fossils, although some crinoid ossicles, rare solitary corals, bivalve fragments and belemnites are present.

Deposition of the Stemwinder Mountain formation was characterized by slower sedimentation rates than that prevailing further east. This resulted in fine-grained, generally organic-rich argillaceous rocks, and only very minor limestones. Although laid down in deeper water, the formation is not considered to be oceanic, but was probably deposited within the deeper part of a relatively shallow back-arc basin that formed east of the main Nicola volcanic arc.

The sedimentary rocks of the Stemwinder Mountain, Hedley and French Mine formations pass stratigraphically upward into the Whistle Creek formation (Figures 11 and 12) which is probably also Late Triassic in age. The formation is 700 to 1200 metres thick and distinguishable from the underlying rocks by a general lack of limestone and a predominance of andesitic to basaltic volcaniclastic material. The base of the Whistle Creek formation is often marked by the Copperfield conglomerate (Figures 11 and 12), a limestone-boulder conglomerate 1 to 200 metres thick that forms an important stratigraphic marker horizon in the district. The conglomerate is well developed west of Hedley where it forms a northerly trending, steeply dipping unit that is traceable for over 15 kilometres along strike. The same conglomerate outcrops in small areas within upfaulted slices along Pettigrew Creek to the south, and as outliers near Nickel Plate and Lookout mountains to the east (Figure 11).

Two Jurassic plutonic suites are recognized in the area. The oldest, the subalkalic, calc-alkaline Hedley intrusions, is economically important and Early Jurassic in age. It forms major stocks up to 1.5 kilometres in

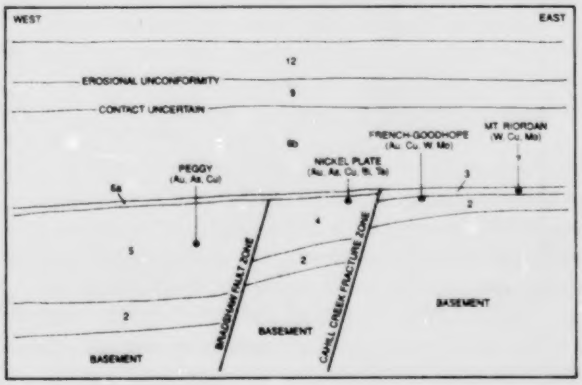
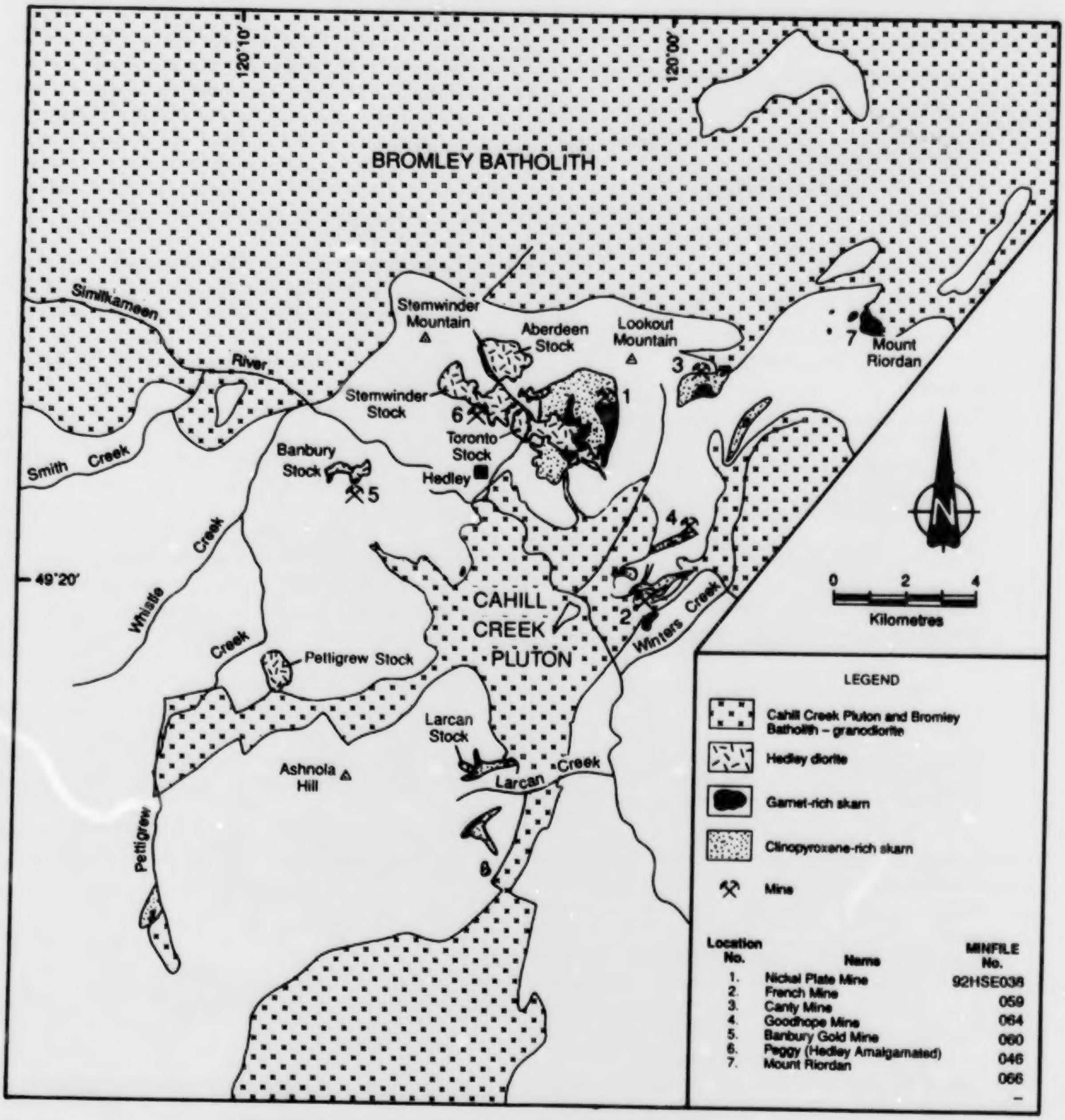


Figure 12. Schematic stratigraphic section of the Hedley district showing location of skarn mineralization in relation to sedimentary facies changes (after Ray *et al.*, 1988). *See* legend for Figure 11.



BROMLEY BATHOLITH
120°10'
120°00'
49°20'
Similkameen
River
Smith Creek
Whistle Creek
Creek
Pettigrew
Winters Creek
Larcan Creek
Stemwinder Mountain
Aberdeen Stock
Lookout Mountain
Stemwinder Stock
Toronto Stock
Hedley
Banbury Stock
Pettigrew Stock
CAHILL CREEK PLUTON
Larcan Stock
Ashnola Hill
Mount Riordan
1
2
3
4
5
6
7
8
N
0
2
4
Kilometres
LEGEND
Cahill Creek Pluton and Bromley Batholith – granodiorite
Hedley diorite
Garnet-rich skarn
Clinopyroxene-rich skarn
Mine
Location No.
Name
MINFILE No.
1. Nickel Plate Mine
2. French Mine
3. Canty Mine
4. Goodhope Mine
5. Banbury Gold Mine
6. Peggy (Hedley Amalgamated)
7. Mount Riordan
92HSE036
059
064
060
046
066
–

Figure 13. Areas of major skarn development in the Hedley district (after Ray *et al.*, 1988).

diameter and swarms of thin sills and dikes up to 200 metres in thickness and over 1 kilometre in length. The sills and dikes are mostly coarse-grained, massive diorites and quartz diorites with minor gabbro, while the stocks range in composition from gabbro through granodiorite to quartz monzonite. Many of the sills and dikes are porphyritic and characterized by coarse phenocrysts of hornblende and zoned plagioclase. When fresh, they are dark coloured, commonly contain minor disseminations of pyrite and pyrrhotite and are often rusty weathered. By contrast, the skarn-altered diorite intrusions are usually bleached.

The Hedley intrusions invade the Upper Triassic rocks over a broad area. Varying degrees of sulphide-bearing calcic skarn alteration are developed within and adjacent to many of these intrusions, particularly the dike and sill swarms. Some previous workers (Billingsley and Hume, 1941; Dolmage and Brown, 1945) considered this plutonic suite to be genetically related to the skarn-hosted gold mineralization in the district, including that at the Nickel Plate, Hedley Mascot, French and Goodhope mines; the geochemical and mapping results presented by Ray *et al.* (1988) support this conclusion.

The second plutonic suite comprises coarse-grained, massive biotite hornblende granodiorite to quartz monzodiorite, of Early to Mid-Jurassic age. It generally forms large bodies, such as the Bromley batholith which outcrops northwest of Hedley, and the Cahill Creek pluton which generally separates the Nicola Group rocks from the highly deformed Apex Mountain complex further to the southeast (Figure 11). Country rocks up to 1.5 kilometres from the margins of the Bromley batholith and Cahill Creek pluton are hornfelsed; some minor skarn alteration is also locally present adjacent to the pluton, but it is generally sulphide poor and not auriferous.

Following lithification of the Nicola Group rocks, two distinct phases of folding took place. The youngest phase resulted in a major north-northeasterly striking, easterly overturned asymmetric anticline which is the dominant structure in the district; the axial plane of this fold dips steeply west. A related, but poorly developed, northerly striking axial planar cleavage is present in some argillites and the axes of smaller scale folds related to this deformation dip gently north and south.

The oldest phase of folding occurred during the emplacement of the Hedley intrusions but is only recognized in the Nickel Plate mine area. It produced small-scale northwesterly striking, gently plunging fold structures that are an ore control at the Nickel Plate mine (Billingsley and Hume, 1941; Dolmage and Brown, 1945) as well as a series of westerly to northwesterly trending fractures. Although there was little movement along these structures, they apparently controlled the emplacement of the Hedley intrusive dikes and the elongate Banbury, Stemwinder and Toronto stocks.

The sulphide-bearing auriferous skarn alteration is commonly developed in the Hedley and French Mine formations, and less frequently in the Stemwinder and Whistle Creek formations. The alteration exhibits a strong spatial association with the Hedley intrusions and occurred during or shortly after their emplacement, as many sills and dikes, as well as the Toronto stock, are altered to endoskarn.

MINERALOGICAL ZONING IN THE HEDLEY SKARNS

Skarn and skarn-related alteration containing pyroxene-garnet-scapolite assemblages with variable amounts of carbonate, quartz, orthoclase, plagioclase, wollastonite, biotite, epidote and chlorite are common and widely distributed in Nicola Group rocks throughout the Hedley district. Alteration varies considerably in grain size, intensity and extent; it ranges from narrow veinlets or irregular patches only centimetres or metres in diameter, up to huge alteration envelopes several hundred metres thick, such as that associated with the Nickel Plate deposit (Figure 13). Other large skarn envelopes are developed adjacent to the French, Goodhope and Canty mines, as well as at Mount Riordan and elsewhere.

On an outcrop scale, a concentric zoning of gangue mineralogy is recognized in the Hedley district. These small-scale zones are commonly the result of reaction between carbonate-rich beds and the skarn-forming fluids, and range from the inner, coarse-grained, more intensely altered skarn assemblages, to the outer, finer grained margins of the envelope. In the ideal form the alteration zones initially develop along fractures adjacent to carbonate-rich beds or marble clasts. A central carbonate-rich core is commonly surrounded by a pinkish brown, garnet-rich zone which passes outwards across a sharp contact into a green-coloured, generally wider, clinopyroxene-rich zone. The clinopyroxene-rich zone may in turn pass outwards to a very narrow section rich in pink potassium feldspar and quartz; this zone is often only a few centimetres thick and is absent in many outcrops.

The outermost alteration zone characteristically comprises a dark purple-brown, siliceous, massive and fine-grained biotite hornfels. Contacts between the inner clinopyroxene-rich and outermost biotite hornfels zones are generally sharp, except where they are separated by thin reaction zones containing potassium feldspar and quartz. The biotite hornfels is commonly cut by a network of thin, light-coloured veinlets of pyroxene and minor amphibole. These fine-grained pyroxene-rich veinlets may be either irregular or exhibit a preferred orientation along microfractures.

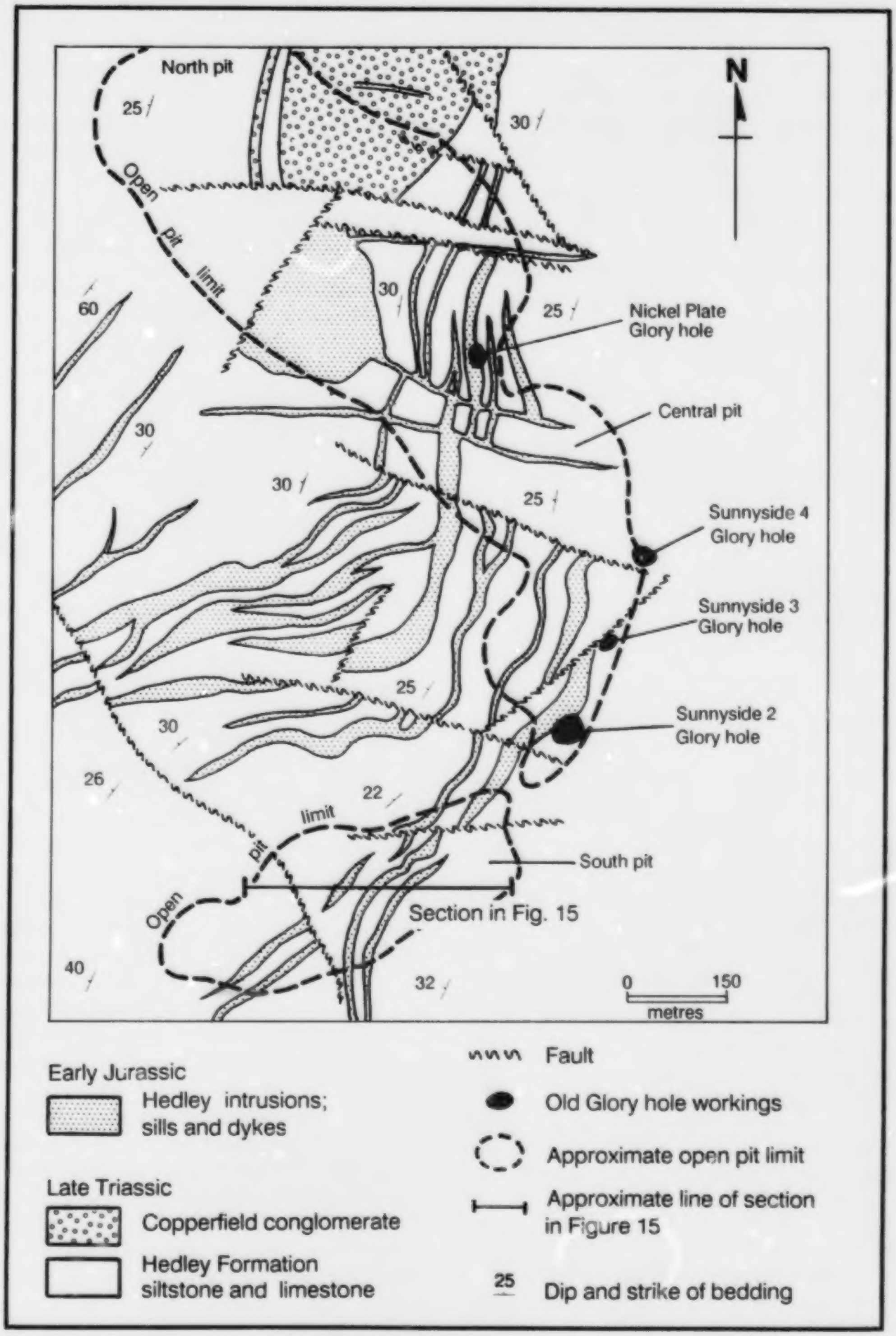

North pit
N
25
30
Open pit limit
60
30
30
25
Nickel Plate Glory hole
Central pit
30
30
25
Sunnyside 4 Glory hole
Sunnyside 3 Glory hole
25
Sunnyside 2 Glory hole
30
26
22
limit
pit
South pit
Open
Section in Fig. 15
40
32
0
150
metres
Early Jurassic
Hedley intrusions; sills and dykes
Late Triassic
Copperfield conglomerate
Hedley Formation siltstone and limestone
Fault
Old Glory hole workings
Approximate open pit limit
Approximate line of section in Figure 15
25
Dip and strike of bedding

Figure 14. General geology of the Nickel Plate deposit, Hedley camp. (Compiled from Bilingsley and Hume, 1941; Lee, 1951; Ray and Dawson, 1988; Simpson, 1988.)

A temporal sequence of skarn development is recognized in the Hedley district (Ray *et al.*, 1988) which is generally as follows: small-scale skarn development begins with the formation of the purple-brown, siliceous biotite hornfels as irregular patches of alteration often centred along bedding plane fractures or crosscutting faults. This hornfels is not a thermal metamorphic feature related to the intrusion of the Hedley sills and dikes but represents the preliminary stage of the skarn forming, metasomatic process and results from passage of the early, hot, skarn-forming fluids along existing fractures. Locally, some Hedley intrusions are overprinted by the biotite hornfels-type alteration which emphasizes the postmagmatic, rather than the synmagmatic, nature of this alteration.

As skarn-forming fluids continued to pass through the sedimentary host rock, the biotite hornfels aureoles expanded in size, and clinopyroxene-rich alteration began to develop in the central parts of the hornfels, usually adjacent to the controlling fractures. As time progressed, the area affected by the clinopyroxene-rich alteration grew larger and development of central zones of garnet-rich alteration began. The garnet-rich alteration, which also steadily expanded outwards, always began within the existing pyroxene-rich zones and developed either along fractures or as reaction rims adjacent to original carbonate-rich sedimentary beds.

When the biotite hornfelsic aureoles reached a certain diameter, which in some outcrops is less than 10 metres in width, their development slowed or stopped. However, both the garnet-rich and pyroxene-rich alteration zones continued their steady growth until they overprinted and completely replaced the hornfelsic aureoles. This replacement results in the formation of thin reaction zones of pink potassium feldspar and quartz separating the pyroxene and outermost biotite hornfelsic zones. The larger skarn envelopes such as those surrounding the Nickel Plate deposit, in contrast to the outcrop-sized skarns, have no peripheral biotite hornfelsic aureoles and the outer portions of the pyroxene-rich alteration are generally in direct, sharp contact with the unaltered host rocks. In many cases these larger envelopes of pyroxene-rich alteration contain small, irregularly distributed remnants of the earlier biotite hornfels and potassium feldspar alteration.

NICKEL PLATE MINE
(MINFILE 092HSE036, 037, 038, 062)

The following data are based on studies by Camsell (1910), Warren and Cummings (1936), Billingsley and Hume (1941), Dolmage and Brown (1945), Lee (1951), and on more recent work by the geological staff of Mascot Gold Mines Limited, Simpson (1986, 1987, 1988) and the British Columbia Geological Survey Branch (Ray *et al.*, 1986b, 1987, 1988; Ettlinger and Ray, 1988).

The Nickel Plate and Hedley Mascot mines were largely developed on a single, very large, westerly dipping skarn-related gold deposit (Figures 14 and 15). It was discovered in 1898 and mined in several underground operations until 1955; it produced approximately 48 million grams of gold from 3.6 million tonnes of ore. Mining resumed in April 1987 at a rate of 2450 tonnes of ore per day from an open pit; on November 18, 1987 Mascot Gold Mines Limited reported mineable reserves of 8.9 million tonnes grading 4.56 grams gold per tonne.*

The gold deposit is hosted within the upper part of the Hedley formation (Figure 12) where a discontinuous zone of garnet-pyroxene skarn alteration, up to 300 metres thick and 6 square kilometres in area, is developed peripherally to the Toronto stock and swarms of Hedley intrusion dikes and sills (Figures 13 and 14). The alteration zone on surface is subcircular in shape and westerly dipping. It lies subparallel to, but locally crosscuts, the gently dipping host rocks which comprise calcareous and tuffaceous siltstone with interbeds of impure limestone. The bulk of the zone extends a considerable distance north and northeast of the Toronto stock within an area of more intense deformation, but to the south the skarn alteration only extends 30 to 150 metres beyond the intrusive contact.

Swarms of Hedley diorite porphyry sills, 1 to 25 metres in thickness, locally make up 40 per cent of the skarn-altered section. In addition, several diorite porphyry dikes have followed west to northwest-trending fault zones (Figure 14); mineralization and alteration tend to follow these dikes, forming deep keels of skarn that locally extend below the main alteration envelope. Skarn development is mostly confined to the Hedley formation, but alteration extends locally up into the overlying Copperfield conglomerate.

The main episode of skarn development occurred during a period of folding that accompanied and immediately followed the emplacement of the diorite sills and dikes. Most of the sills and dikes within the skarn envelope are bleached and altered. The exoskarn is dark green to brown coloured and typically consists of alternating layers of garnet-rich and clinopyroxene-rich alteration which reflect the original sedimentary bedding. Overall however, the Nickel Plate skarn is pyroxene dominant compared to garnet.

The concentric mineralogical zoning commonly observed in the small skarn envelopes in the district (Ray *et al.*, 1987, 1988) is not clearly defined at the Nickel Plate mine, probably due to large-scale multiple and complex overprinting of the skarn alteration. Garnet-rich skarn is usually found in the cores of the alteration envelopes but metasomatic overprinting has eliminated most of the initial biotite hornfelsing, resulting in a generally sharp transition from pyroxene skarn to unaltered sediment. This transition represents the economically important "marble line" described by Billingsley and Hume (1941). Preliminary studies suggest that at least two stages of mineral growth are present in the skarn. The main minerals formed during the early stage were biotite, orthoclase, iron-rich pyroxene, garnet, quartz, wollastonite and carbonate. The pink to brown-coloured garnets are generally anhedral but are euhedral where they grew adjacent to carbonate. They are markedly birefringent and range between Ad 25 and Ad 80 mole per cent (Figure 16A). Like garnets developed in all the gold-bearing skarns in the Hedley district and at Mount Riordan, the Nickel Plate garnets generally contain less than 1 per cent MnO. The pyroxenes at Nickel Plate usually form small anhedral crystals that are also low in manganese and commonly range between Hd 40 and Hd 75 mole per cent (Figure 17A).

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* In Dec. 1988 Corona Corporation reported 8.25 million tonnes grading 3.02 grams gold per tonne at Nickel Plate.

The later stage of skarn alteration at Nickel Plate is largely restricted to the outer and lower margins of the envelope, normally within 100 metres of the skarn front. This late-stage alteration is rarely seen in the central or upper parts of the skarn zone, except along fractures or

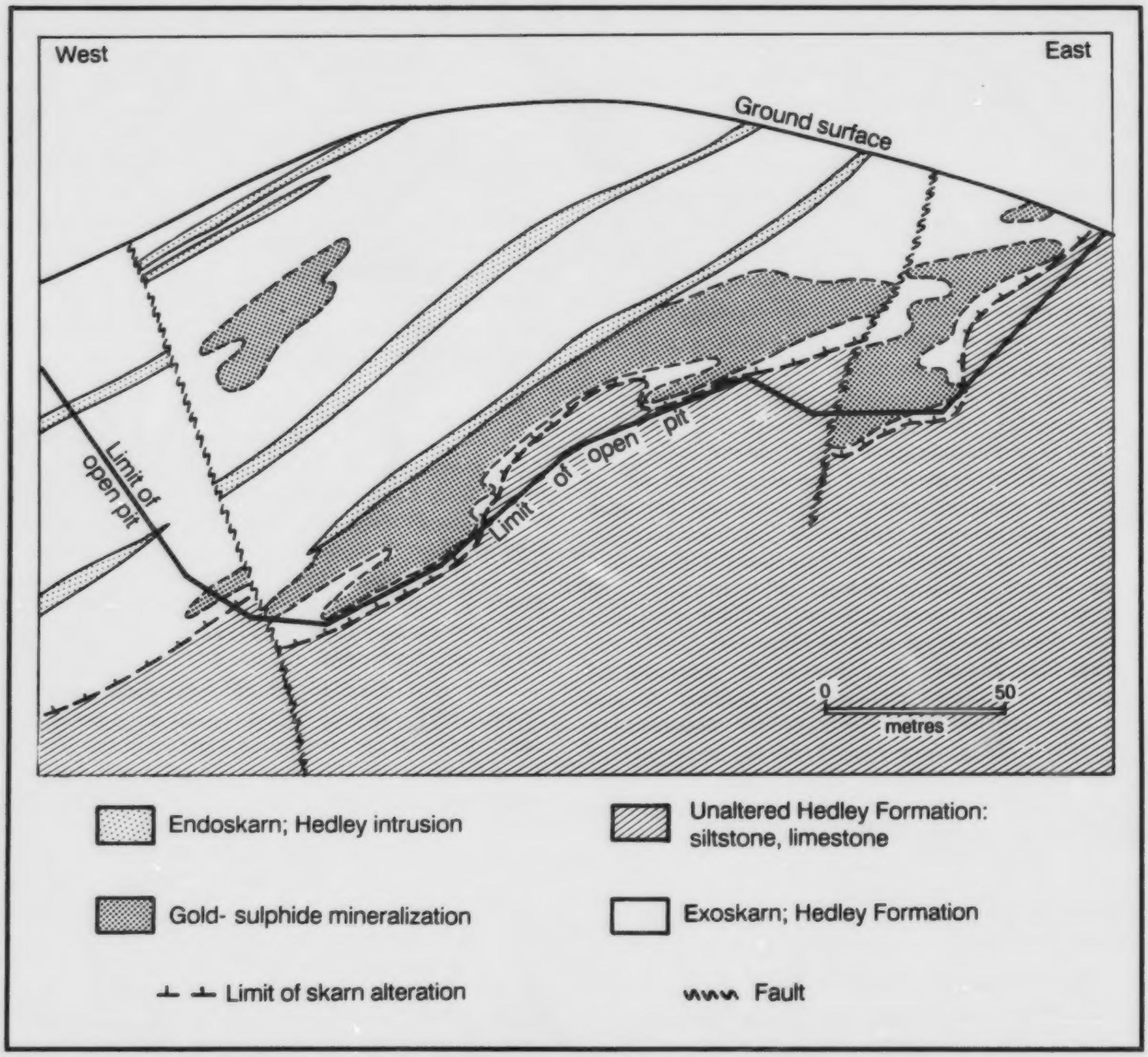
West
East
Ground surface
Limit of open pit
Limit of open pit
0
50
metres
Endoskarn; Hedley intrusion
Gold- sulphide mineralization
Limit of skarn alteration
Unaltered Hedley Formation: siltstone, limestone
Exoskarn; Hedley Formation
Fault

Figure 15. Generalized section through the southern part of the Nickel Plate deposit, Hedley camp. For location *see* Figure 14. (Compiled from Simpson, 1988 and unpublished reports and drill sections, courtesy of Mascot Gold Mines Ltd.)

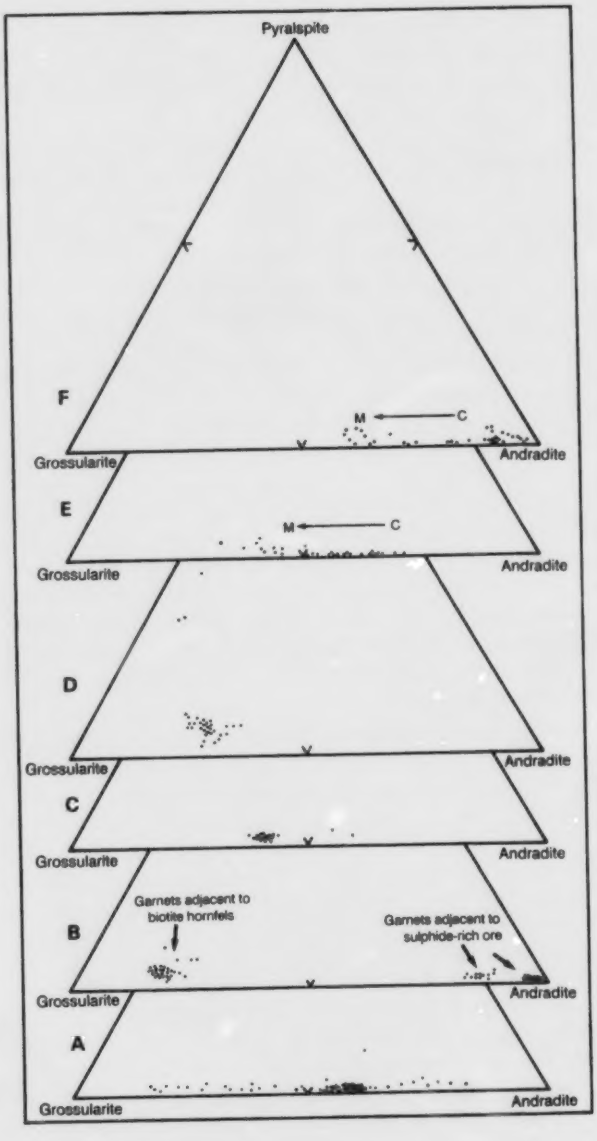

Figure 16. Composition of exoskarn garnets from the Hedley camp.*
A = Nickel Plate mine (65 analyses).
B = French mine (56 analyses).
C = Canty mine (20 analyses).
D = Goodhope mine (33 analyses).
E = Peggy (29 analyses).
F = Mount Riordan (35 analyses).
Arrows in Figures 16E and 16F indicate direction of crystal growth from cores (C) to margins (M).
*Analyses by G.E. Ray and G.L. Dawson at The University of British Columbia, Vancouver, except in Figure 16A which includes 25 analyses by A.D.Ettlinger at Washington State University, U.S.A.

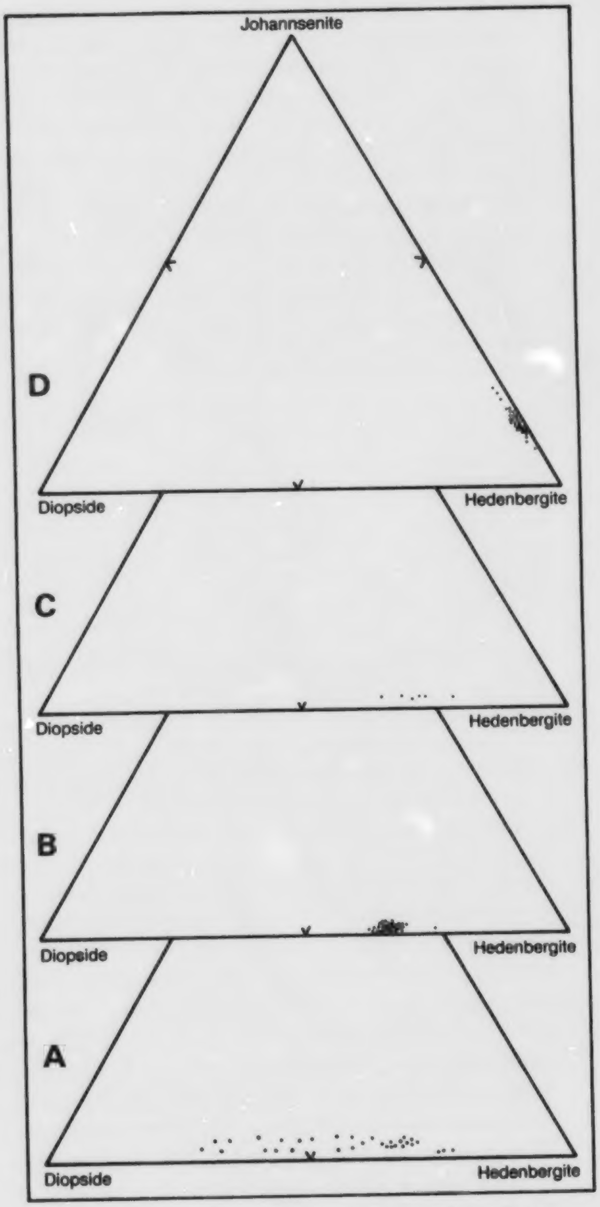

Figure 17. Composition of exoskarn pyroxenes from the Hedley camp.*
A = Nickel Plate mine (38 analyses).
B = French mine (35 analyses).
C = Canty mine (5 analyses).
D = Goodhope mine (29 analyses on coarse, tabular pyroxene crystals).
*Analyses by G.E. Ray and G.L. Dawson at The University of British Columbia, Vancouver, except in Figure 17A which includes 23 analyses by A.D.Ettlinger at Washington State University, U.S.A.

dike and sill margins. It resulted in the introduction of sulphides and gold, accompanied by abundant scapolite, calcite and quartz with minor amounts of epidote, chlorite, clinozoisite, prehnite, orthoclase and local axinite. Dolmage and Brown (1945) describe the scapolite as dipyre, while XRD analyses indicate some mizzonite is also present (Ray *et al.* 1986b). The ferromagnesian minerals at the Nickel Plate mine, and in other skarns throughout the district, are remarkably fresh and show little evidence of widespread retrograde alteration.

The gold-bearing sulphide zones normally form semi-conformable, tabular bodies situated less than 100 metres from the outer and lower skarn margins (Figure 15). They are both lithologically and structurally controlled along northwesterly plunging minor folds, fractures and sill-dike intersections (Billingsley and Hume, 1941; Dolmage and Brown, 1945).

There are significant geochemical and mineralogical variations throughout the deposit. The main Nickel Plate ore zone near the Nickel Plate glory hole (Figure 14), in the northern part of the deposit, consists primarily of arsenopyrite, pyrrhotite and chalcopyrite with carbonate, pyroxene, scapolite, garnet and quartz. Arsenopyrite often forms coarse, wedge-shaped crystals up to 1 centimetre in length and the sulphides occur as disseminations and fracture fillings within the exoskarn. The Sunnyside ore zones in the central part of the deposit (Figure 14) are strongly controlled by either sill-dike intersections or fold hinges. Although the sulphide mineralogy and textures resemble those in the Nickel Plate zone, pyrrhotite dominates in the Sunnyside zones. The mineralization in the southern part of the deposit comprises lenses and pods of massive to semi-massive sulphide mineralization; it is noticeably richer in chalcopyrite and contains higher silver and zinc values.

Grain boundary relationships suggest the following three stages of sulphide deposition: (1) pyrite; (2) arsenopyrite and gersdorffite (NiAsS); and (3) pyrrhotite, chalcopyrite and sphalerite (R. Simpson, personal communication, 1987). Gold mineralization is related to the latter two stages, and minor amounts of magnetite are associated with the first and last sulphide phases. Pyrrhotite and arsenopyrite are the most common sulphides. Present in lesser amounts, but locally dominant, are pyrite, chalcopyrite, and cadmium-rich sphalerite with minor amounts of magnetite and cobalt minerals. Trace minerals include galena, native bismuth, gold, electrum, tetrahedrite, native copper, gersdorffite, marcasite, molybdenite, titanite, bismuth tellurides (hedleyite, tetradynite), cobaltite, erythrite, pyrargyrite and breithauptite. Trace amounts of maldonite (Au_2Bi) have recently been identified (Ettlinger and Ray, 1988) but no scheelite has been seen in the deposit. The native gold, with hedleyite, occurs as minute blebs, generally less than 25 microns in size, within and adjacent to grains of arsenopyrite and gersdorffite. In the South pit area (Figure 14), electrum occurs in close association with chalcopyrite, pyrrhotite, sphalerite and native bismuth; it tends to be concentrated in microfractures within and around the sulphides.

A recent preliminary statistical study (Simpson, 1987) based on analyses of over 300 mineralized samples from various ore zones in the Nickel Plate deposit, showed the following correlation coefficients: Au:Bi, 0.94; Ag:Cu, 0.84; Bi:Co, 0.62; Au:Co, 0.58; Au:As, 0.46; Au:Ag, 0.28; and Au:Cu, 0.17. The strong positive correlation between gold and bismuth reflects the close association of native gold with hedleyite, while the moderate positive correlation between gold, cobalt and arsenic confirms the observed association of gold, arsenopyrite and gersdorffite. The high positive correlation between silver and copper may indicate that some silver occurs as a lattice constituent in the chalcopyrite. The gold and silver values are relatively independent of each other despite the presence of electrum, and there is generally a low correlation between gold and copper. Gold:silver ratios in the Nickel Plate and Sunnyside zones are greater than 1 with silver averaging 2 ppm. By contrast, in the southern part of the deposit where electrum is present, the Au:Ag ratio is less than 1, with silver averaging 17 ppm.

Bismuth averages 20 ppm but may reach concentrations of several hundred parts per million in areas with higher gold values. Nickel and cobalt values normally range from 100 to 200 ppm but both locally exceed 2 per cent in areas containing abundant visible erythrite and high gold values. Copper commonly exceeds 0.5 per cent over intervals of several metres, particularly in the sulphide-rich South pit area (Figure 14). Secondary gold enrichment is also present in some weathered, near-surface, oxide-rich zones and along certain faults. The resulting red hematitic clay zones may carry gold grading over 34 grams per tonne.

FRENCH MINE (OREGON)
(MINFILE 092HSE059)

The abandoned French mine lies approximately 5 kilometres south of the Nickel Plate mine (Figure 13). It has had a history of intermittent mining but the precise production figures for this property are uncertain. The National Mining Inventory (Table 2-10-1, Ray *et al.*, 1987) reports approximately 1615 kilograms of gold and 124 kilograms of silver obtained from a total of 79 000 tonnes of ore. However, the British Columbia Geological Survey Branch MINFILE (*see* Table 2) reports 1362 kilograms of gold, 181 kilograms of silver and 20.5 tonnes of copper derived from 68 000 tonnes of ore.

Mineralization is hosted by limestones, limestone breccias and calcareous, tuffaceous sediments of the French Mine formation, close to their contact with the Cahill Creek pluton. However, the mineralization is believed to be related to several dioritic dikes and sills of the Hedley intrusions that cut the mine area. Skarn alteration occupies the hinge portion of a faulted anticline, and the sulphide-rich orebodies reach up to 40 metres in length and 3 metres in width (Billingsley, 1936). The auriferous orebodies contain arsenopyrite, pyrite, chalcopyrite, covellite, bornite and pyrrhotite with sporadic coarse molybdenite and scheelite. Copper values range up to 6 per cent over several metres (Billingsley, 1936) and chip sampling along a 35-metre, gold-rich skarn section averaged 0.68 per cent WO_3, with maximum values of 1.3 per cent over 3 metres (Ray *et al.*, 1988). Grab samples assayed up to 32 grams gold and 150 grams silver per tonne, 10 per cent copper and 0.26 per cent bismuth, as well as containing sporadically anomalous values of cobalt, antimony and molybdenum. Preliminary geochemical data suggest there is a good correlation between copper and silver, but a poor correlation between copper and gold; this relationship is also noted at the Nickel Plate mine.

The alteration is marked by garnet, clinopyroxene, and calcite, with variable quantities of axinite, twinned plagioclase, wollastonite, clinozoisite, epidote, biotite, potassium feldspar, scapolite and quartz. Mineralogical zoning is observed at the French mine; an outer envelope of biotite hornfels passes inwards to the later developed, crosscutting garnet-pyroxene assemblages. Unlike the garnet crystals at Nickel Plate mine, which are commonly birefringent, those at the French mine tend to be isotropic. Microprobe analyses (Figure 16B) suggest only relatively minor compositional zoning exists in most garnet crystals. However, microprobe studies suggest that the garnets present in the ore zone are highly enriched in iron, ranging in composition from Ad 80 to Ad 100 mole per cent while garnets from veinlets that cut the biotite hornfels in the outer parts of the envelope range from Ad 13 to Ad 25 mole per cent (Figure 16B). The pyroxene crystals have a low manganese content (1 per cent), and show little compositional zoning, commonly ranging from Hd 63 to Hd 67 mole per cent (Figure 17B).

CANTY MINE (PITTSBURG, BOSTON GREENWOOD)
(MINFILE 092HSE064)

The Canty property lies approximately 2 kilometres northeast of the Nickel Plate mine (Figure 13), but the geology is not well known, due to poor exposure. Between 1939 and 1941 approximately 16 kilograms of gold were produced from 1483 tonnes of ore. Rice (1947) briefly described gold-arsenopyrite-rich mineralization in a faulted and folded zone of skarn-altered sedimentary rocks similar to those at the Nickel Plate mine. He also noted the presence of a 120 to 130-metre-wide "granitic" dike; recent examination of drill core abandoned on the property indicates that skarn-altered, dioritic Hedley intrusions are also present. Mapping (Ray *et al.*, 1987, 1988) shows that the area surrounding the Canty mine is underlain mostly by ash and lapilli tuffs belonging to the lower part of the Whistle Creek formation, and drilling by Mascot Gold Mines Ltd. suggests that the mineralization is hosted in these rocks (L. Saleken and R. Simpson, personal communications, 1988). The mine property lies adjacent to the Cahill Creek fracture zone (Figures 11 and 13) which may have played some role in controlling the mineralization. Metallic minerals identified include arsenopyrite, pyrite, chalcopyrite, pyrrhotite and native bismuth. Mineralized grab samples from the Canty mine dump assayed up to 35 grams per tonne gold, 0.6 per cent cobalt, 52 ppm molybdenum, 168 ppm antimony and 29 per cent arsenic. Alteration assemblages include calcite, garnet, clinopyroxene, quartz, scapolite and epidote. Microprobe analyses of garnet crystals suggest very little compositional variation or zoning throughout individual grains; they most commonly range from Ad 35 to Ad 45 mole per cent (Figure 16C), while the low-manganese clinopyroxenes range in composition from Hd 63 to Hd 72 mole per cent (Figure 17C).

GOODHOPE MINE
(MINFILE 092HSE060)

The Goodhope gold skarn is situated 4 kilometres southeast of Nickel Plate mine (Figure 13), and lies within the same flat-lying stratigraphic package of marbles and metasediments that hosts the French mine deposit (Ray *et al.*, 1988). Intermittent mining in the 1940s and in 1982 reportedly resulted in the production of 178 kilograms of gold, 120 kilograms of silver and 602 kilograms of copper from 11 410 tonnes of ore.*

Mineralization at Goodhope consists of disseminated to massive arsenopyrite and pyrrhotite, with sporadic chalcopyrite, pyrite, native bismuth, molybdenite and hedleyite; mineralized grab samples assayed up to 94 grams per tonne gold. In some aspects this skarn resembles the Nickel Plate system in being enriched in gold, arsenic and bismuth tellurides, yet it also shows some distinct similarities to the gold-poor Mount Riordan skarn situated 8 kilometres further northeast. These similarities include sporadic enrichment in scheelite and magnetite, and the presence of coarse, euhedral, variably

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*These MINFILE production figures quoted in Table 2 differ slightly from the National Mineral Inventory production data quoted in Ray *et al.*, 1987, Table 2-10-1.

coloured garnet crystals. In contrast to the Nickel Plate skarn which is pyroxene dominant, the skarns at Goodhope and Mount Riordan are garnet rich. One unusual feature of the Goodhope skarn is the presence of large, tabular, optically twinned, euhedral hedenbergite crystals, that generally range up to 2 centimetres in length, although some individual crystals over 9 centimetres long are present. The garnets and pyroxenes in the Goodhope skarn are the only ones in the Hedley area that show some late alteration, being locally partially replaced by an unusual, dark, grass-green-coloured amphibole. The garnets may occur as euhedral crystals up to 1 centimetre in diameter that are markedly birefringent and sector twinned.

Microprobe analyses of garnets and pyroxenes from the Goodhope mine reveal that they are manganese-rich relative to those in the other Hedley skarns (Figures 16D and 17D). Garnets range compositionally from Ad 10 to Ad 30 mole per cent (Figure 16D) but individual crystals generally show very little compositional zoning; they contain up to 11 mole per cent pyralspite (pyrope + almandine + spessartine) but some crystals contain narrow growth zones of manganese enrichment marked by up to 45 mole per cent pyralspite.

PEGGY (HEDLEY AMALGAMATED)
(MINFILE 092HSE066)

This property is situated 4 kilometres west of the Nickel Plate mine and lies close to the intrusive contact between the quartz diorite Stemwinder stock and steeply dipping calcareous siltstones, argillites and thin limestones of the Upper Trassic Stemwinder formation. The sediments are also cut by several altered dioritic sills of the Hedley intrusions. The British Columbia Minister of Mines Annual Report for 1947 reports the presence of at least three adits on the property, one of which exceeded 200 metres in length. The skarn-related mineralization is both lithologically and structurally controlled and has been affected by either syn or post-mineralization faulting that resulted in the growth of botryoidal pyrite and pyrrhotite. Other sulphides include arsenopyrite and traces of chalcopyrite, covellite and sphalerite; these are disseminated throughout the garnet-pyroxene skarn, although the richer mineralization is confined to fault zones. Some minor, thin quartz veining is also reported in the skarns. Grab samples of sulphide-rich material collected from the dump at the Peggy workings gave maximum assay values of 29 grams gold and 16 grams silver per tonne, with 0.52 per cent copper, 700 ppm cobalt, 2.5 per cent arsenic and 10 ppm antimony; no anomalous bismuth values were recorded.

The mineralogy of the skarns at the Peggy property resembles the Nickel Plate mine skarns; they are pyroxene dominant and the pyroxenes are generally fine grained and anhedral. Most of the garnets are optically birefringent, but some crystals contain isotropic cores. Other minerals present include carbonate, quartz, scapolite, epidote, wollastonite, sericite, chlorite, orthoclase and prehnite. Microprobe analyses indicate the isotropic cores of the garnets are relatively enriched in iron compared to the birefringent margins. Individual crystals vary from those that possess no progressive compositional variations from core to rim, to garnets that become steadily more grossularitic towards the rims (Figures 16E and 43E). Both the garnets and pyroxenes at the Peggy mine have a low manganese content; the former range from Ad 30 to Ad 70 mole per cent (Figure 16E).

MOUNT RIORDAN (SHAMROCK, PATRICIA)
(MINFILE 082ESW107)

The Mount Riordan skarn is situated 7 kilometres east-northeast of the Nickel Plate mine (Figure 13). It is characterized by tungsten-copper mineralization and is not generally gold enriched, although locally the sulphide mineralization does assay up to 19 grams silver per tonne. It is not listed in Table 2 but is included in this study because it is tentatively believed to form part of the Hedley precious metal skarn system (Ray *et al.*, 1988).

The Mount Riordan skarn is believed to be hosted by what were originally massive limestones of the shallow-dipping French Mine formation; the skarns mainly comprise coarse crystalline garnet in which almost no original sedimentary structures are recognizable. There is some minor epidote, quartz, wollastonite, actinolite, chlorite and clinopyroxene present, but the latter is not abundant. The euhedral garnets vary considerably in colour; black, red, pink, brown, green and yellow-green varieties are present. In a few cases the crystals exceed 6 centimetres in diameter and show prominent growth zonations.

Massive garnet skarn is well exposed over a 0.6 square kilometre area, although discontinuous outcrops extend for more than 1.5 kilometres. Locally, the skarn contains pockets and disseminations of magnetite intergrown with variable amounts of pyrrhotite, pyrite, chalcopyrite and traces of bornite. Visible fine to coarse-grained scheelite is also present over a wide area but is best developed where the skarn contains veins of carbonate and quartz. Various grab samples of sulphide-rich mineralization assayed up to 5 per cent WO_3, 0.7 per cent copper, 310 ppm molybdenum, 19 grams silver per tonne and 0.11 per cent zinc (Ray *et al.*, 1988). Gold values were generally low (40 ppb) but one magnetite-rich, pyrrhotite and chalcopyrite-bearing sample assayed 1.69 grams gold per tonne.

Optically, the garnets in the Mount Riordan skarn are birefringent and many contain irregular shaped cores of salmon-pink garnet, with abundant small inclusions of quartz and pyroxene. These pink cores are commonly overgrown by clear, colourless, euhedral, sector-twinned and birefringent margins, although in rare instances the extreme outer rims may also be pink coloured like the cores. Microprobe analyses indicate that the garnets, like those elsewhere in the Hedley camp, have a very low manganese content (0.5 per cent) ranging in composition from Ad 52 to Ad 97 mole per cent (Figure 16F). Microprobe traverses indicate marked compositional zoning in the garnets with iron-rich cores and more aluminous margins (Figures 16F and 43F). This crystal compositional zoning at Mount Riordan, from andraditic cores to grossularitic rims, is similar to that seen in garnets from the Peggy mine. It may indicate that both skarns initially formed in an oxidizing environment, and that the hydrothermal systems later evolved under more reducing conditions. This more reduced period may have coincided with the deposition of the sulphides and gold.

The skarn mineralization may be genetically related to either a small microdiorite intrusion that outcrops on the summit of Mount Riordan, or to a porphyritic granodiorite body that is poorly exposed along the eastern base of the mountain and which may also underlie the main skarn zone. Both these intrusions predate and are partially overprinted by the skarn alteration.

GEOCHEMICAL CHANGES ASSOCIATED WITH SKARN ALTERATION AND MINERALIZATION

Many previous workers, including Camsell (1910), Billingsley and Hume (1941) and Dolmage and Brown (1945), noted a spatial association between the Nickel Plate auriferous skarn mineralization and the Hedley intrusions, leading them to suggest a genetic relationship. Preliminary geochemical data presented by Ray *et al.* (1988) and additional analyses included in this report (Appendix 2 and 4) support this conclusion and suggest that the iron in the exoskarn was derived from the Hedley intrusions. It must be noted that the apparent chemical

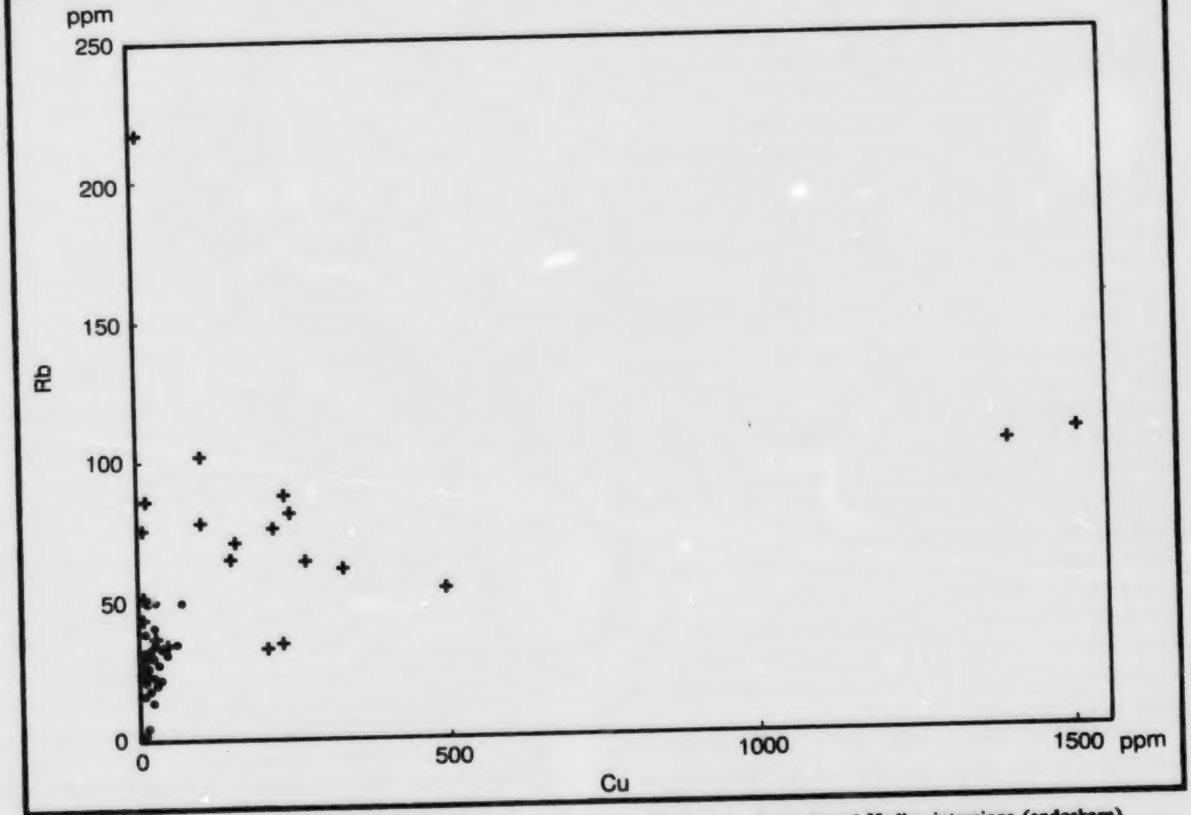


Figure 18. Plot of Rb versus Cu illustrating the increase in these elements in skarn-altered Hedley intrusions (endoskarn) compared to unaltered Hedley intrusions; 25 samples of endoskarn (crosses) and 29 samples of unaltered intrusion (dots).

changes discussed below are based on quantitative values presented in Appendix 2 to 5 and no allowance has been made for any volume changes, as described by Gresens (1967) that may have occurred during the metasomatic process. A joint study to determine any skarn-related volume changes in the Hedley district is currently being conducted at the University of Waterloo under the leadership of Dr. E.C. Appleyard.

Appendix 3 and 5 compare the trace element geochemistry of the unaltered and altered (endoskarn) dioritic Hedley intrusions; many elements, including Zr, Y, Co, Ni and Mo, show no apparent variation between the unaltered and skarn-altered rocks. However, notable exceptions are As, Rb and Cu (Appendix 3 and 5) which show major increases in the endoskarn compared to the unaltered diorite (Figure 18).

Data presented in Appendix 2 and 4 demonstrate that many major elements including calcium, aluminum and titanium show little or no variation between the unaltered and skarn-altered dioritic Hedley intrusions. Other elements, however, notably total iron, and to a lesser extent silica, potassium and sodium, show progressive compositional changes during the skarning process. Figure 19 shows that, compared to unaltered Hedley intrusions, the skarn-altered (endoskarn) diorites have higher values of potassium and sodium. Likewise, Figure 20A illustrates that the skarning process results in a considerable loss of total iron and a modest gain in silica; this conclusion is supported by a plot of total iron:titanium against silica:titanium (Figure 20B). The genetic implications of this iron loss are illustrated in Figure 21 which compares endoskarn and exoskarn core samples from three drill holes that intersect different parts of the Nickel Plate deposit. All the samples collected from these holes exhibit varying degrees of skarn alteration. The endoskarn samples are dioritic Hedley intrusions while the exoskarn is largely altered calcareous siltstone and limestone of the Hedley formation; the analytical results for the exoskarn sample are presented in Table 1-5-4, Ray *et al.*, 1988. It should be noted that hole DDH 401 was collared outside the open-pit perimeter and intersected barren, generally fine-grained pyroxene-rich skarn; hole DDH 73 intersected subeconomic skarn-hosted mineralization west of the open-pit boundary, and hole DDH 261 was collared within the planned open-pit area (Figure 21A) and cut ore-grade skarn mineralization.

In the barren intersection (Figure 21B) the two fields outlining the iron-silica contents of the exoskarn and endoskarn are relatively close together and the endoskarn is the more iron-rich. By contrast, in the subeconomic and economic intersections (Figures 21C and 21D) the iron content of the exoskarn greatly exceeds that of the endos-

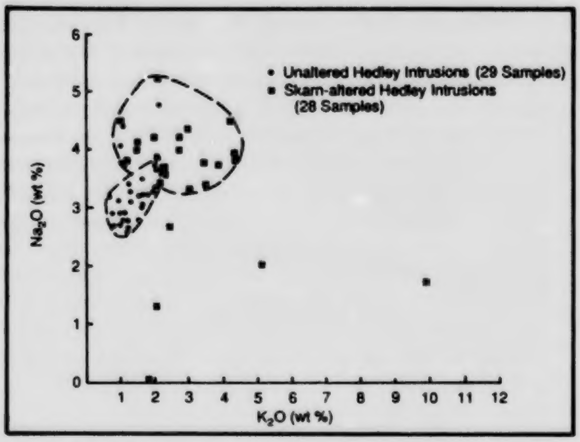


Figure 19. Plot of Na_2O versus K_2O illustrating increases in sodium and potassium in skarn-altered Hedley intrusions (endoskarn) compared to unaltered Hedley intrusions (after Ray *et al.*, 1988).

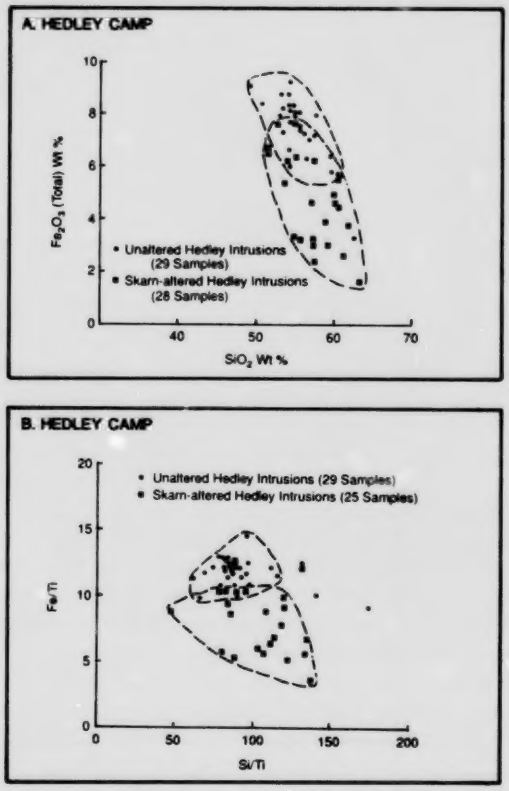


Figure 20. Plots comparing the silica and iron contents of unaltered and skarn-altered (endoskarn) Hedley intrusions (after Ray *et al.*, 1988).
A = Fe_2O_3 (total) versus SiO_2 weight per cent.
B = Fe/Ti versus Si/Ti.

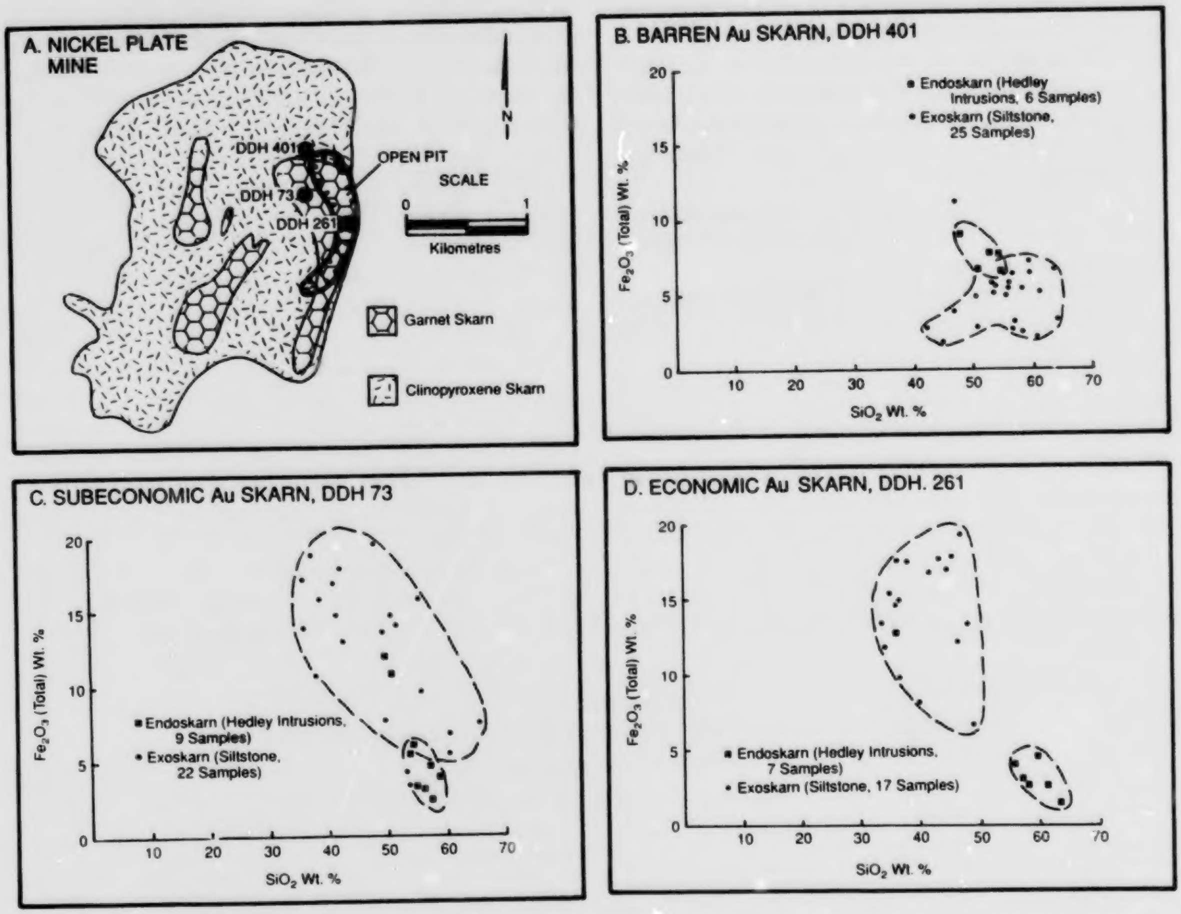


Figure 21. Plot of Fe_2O_3 (total) weight per cent versus SiO_2 weight per cent comparing barren, subeconomic and economic skarn from three diamond-drill holes at Nickel Plate mine.
A = Nickel Plate mine showing location of drill holes in relation to the open pit and skarn zone.
B = Barren skarn intersection, DDH 401.
C = Subeconomic skarn intersection, DDH 73.
D = Economic skarn intersection, DDH 261.
Note: transition from barren to auriferous skarn is accompanied by a decrease in iron in the endoskarn Hedley intrusions and a corresponding increase in iron in the exoskarn sedimentary rocks (after Ray *et al.*, 1988).

karn. In these two holes the exoskarn shows a major increase in iron and decrease in silica, matched by a corresponding drop in iron and rise in the silica in the endoskarn.

To summarize, progressive skarn alteration of the Hedley intrusions results in no apparent change in the calcium content, a modest increase in the sodium, potassium and silica contents and a major decrease in total iron. The adjacent skarn-altered sedimentary rocks (exoskarns) are correspondingly enriched in iron and depleted in silica. These results suggest that relatively few metasomatic geochemical changes took place in the outer parts of the Nickel Plate skarn envelope and that the most dramatic metasomatism occurs in the mineralized parts of the skarn where there was presumably greater fluid movement. They also suggest that the Hedley intrusions were probably the source of the iron enrichment in the adjacent exoskarn, and thus may also be the primary source of the skarn-hosted gold.

DISTRICT-WIDE METALLOGENIC ZONING IN THE HEDLEY CAMP

The location and distribution of areas underlain by major skarn alteration in the Hedley district are shown in Figure 13. The auriferous deposits in the Hedley camp have formerly been regarded as relatively uniform gold-(copper-cobalt-arsenic) skarn mineralization (Camsell, 1910; Billingsley and Hume, 1941; Ray *et al.*, 1987). However, the Mount Riordan skarn is distinct in being gold poor, tungsten and copper rich, and garnet dominant in contrast to the pyroxene-dominant Nickel Plate skarn. The following relationships are possible:

(1) The Mount Riordan skarn is unrelated to the gold-rich skarns further to the west and their relatively close proximity is coincidental.

(2) The two skarn types are related and were derived from a common basement source, but were emplaced at different, possibly widely separated times.

(3) The Mount Riordan skarn is temporally and genetically related to the Nickel Plate skarn and other gold skarns in the district.

A program of U:Pb zircon radiometric dating presently in progress may resolve this question. However based on data currently available, the third alternative is favoured, partly because the mineralization and mineralogy in the vicinity of French and Goodhope mines show geochemical and mineralogical characteristics intermediate between the Mount Riordan and Nickel Plate skarns. For example, the Goodhope skarn contains coarsely crystalline, variably coloured garnet similar to Mount Riordan while other skarn occurrences close by are magnetite rich. Both the Goodhope and French mines locally contain abundant fine and coarse-grained scheelite together with the gold and copper. Underground chip sampling along a 35-metre section of gold-rich skarn at the French mine averaged 0.68 per cent WO_3 with maximum values of 1.32 per cent over 3 metres (Westervelt Engineering Ltd., unpublished report, January 12, 1978). Thus the Hedley camp may possess a district-wide metallogenic zoning with gold and arsenic-rich, tungsten-poor skarns in the west through to tungsten-rich, gold and arsenic-poor skarns to the east. This may have important implications elsewhere in the Cordillera, as some tungsten skarn districts, particularly those associated with fracture-related basin margins, may have gold-bearing skarn potential.

The east-to-west metallogenic zoning is also accompanied by changes in skarn mineralogy, host rock geology and composition of the skarn-related intrusions (Table 3).

TABLE 3
CHARACTERISTICS OF EAST-WEST SKARN VARIATION ACROSS THE HEDLEY DISTRICT
(modified from Ray *et al.*, 1988)

	WEST		**EAST**
Features	**Nickel Plate Mine**	**French and Goodhope Mines**	**Mount Riordan**
Skarn mineralogy	Banded, clinopyroxene-dominant skarn. Garnets generally anhedral and brown coloured.	Locally clinopyroxenes or garnet-dominant skarn. Both euhedral and anhedral garnet. Variably coloured garnet.	Massive, garnet-dominant skarn. Euhedral garnet with highly variable colour.
Degree of skarn alteration	Sedimentary structures often preserved in skarn.	Sedimentary structures locally preserved.	No primary structures preserved.
Skarn metallogeny	Au,As,Cu,Co,Bi,Te,Ag,Ni,Sb	Au,Cu,W,Co,Mo,Bi,As,Ag,Te,Sb (Sn)	Cu,W,Ag
Skarn-related intrusions	I-type, dioritic, calc-alkaline Hedley intrusions.	I-type, dioritic, calc-alkaline Hedley intrusions.	I-type, calc-alkaline, diorite or granodiorite?
District host-rock geology	Siltstones and limestones of the Hedley formation.	Limestone breccia and limy sediments of the French Mine formation.	Probably massive limestone of the French Mine formation.
Initial $^{87}Sr/^{86}Sr$ of intrusions	0.7038		0.7044

The skarns in the western and central parts of the district are clinopyroxene rich and epidote poor, while the Mount Riordan skarn is garnet and epidote rich and clinopyroxene poor. The nature and colour of the garnets also vary across the district; in the western skarns, including those at the Nickel Plate mine, they are generally anhedral and uniformly pink to brown coloured, while at the Goodhope mine and Mount Riordan they are coarsely euhedral and vary from brown-red to green and black in colour.

The composition of the skarn-related intrusions varies across the district from diorite at the Nickel Plate, Canty, Goodhope and French mines to possible granodiorite at Mount Riordan (Table 3). Likewise, the initial ^{87}Sr:^{86}Sr ratios of these intrusions change from 0.7038 in the dioritic Hedley intrusions in the west to 0.7044 in the granodiorite at Mount Riordan (R. Armstrong, personal communication, 1988). These variations in skarn mineralogy, intrusion composition and initial ^{87}Sr:^{86}Sr ratios may reflect east-to-west changes in the basement rocks underlying the Nicola Group which probably formed the source of the skarn-related intrusions.

DIVIDEND-LAKEVIEW MINE
(MINFILE 082ESW001)

Gold-bearing skarn mineralization enriched in arsenic, cobalt and bismuth outcrops on the eastern slope of Kruger Mountain approximately 3 kilometres southwest of Osoyoos (Figure 22). Between 1907 and 1939, 504 kilograms of gold, 88 kilograms of silver, 73 tonnes of copper, 71 kilograms of lead and 71 kilograms of zinc were produced from 111 250 tonnes of ore (Appendix 1).

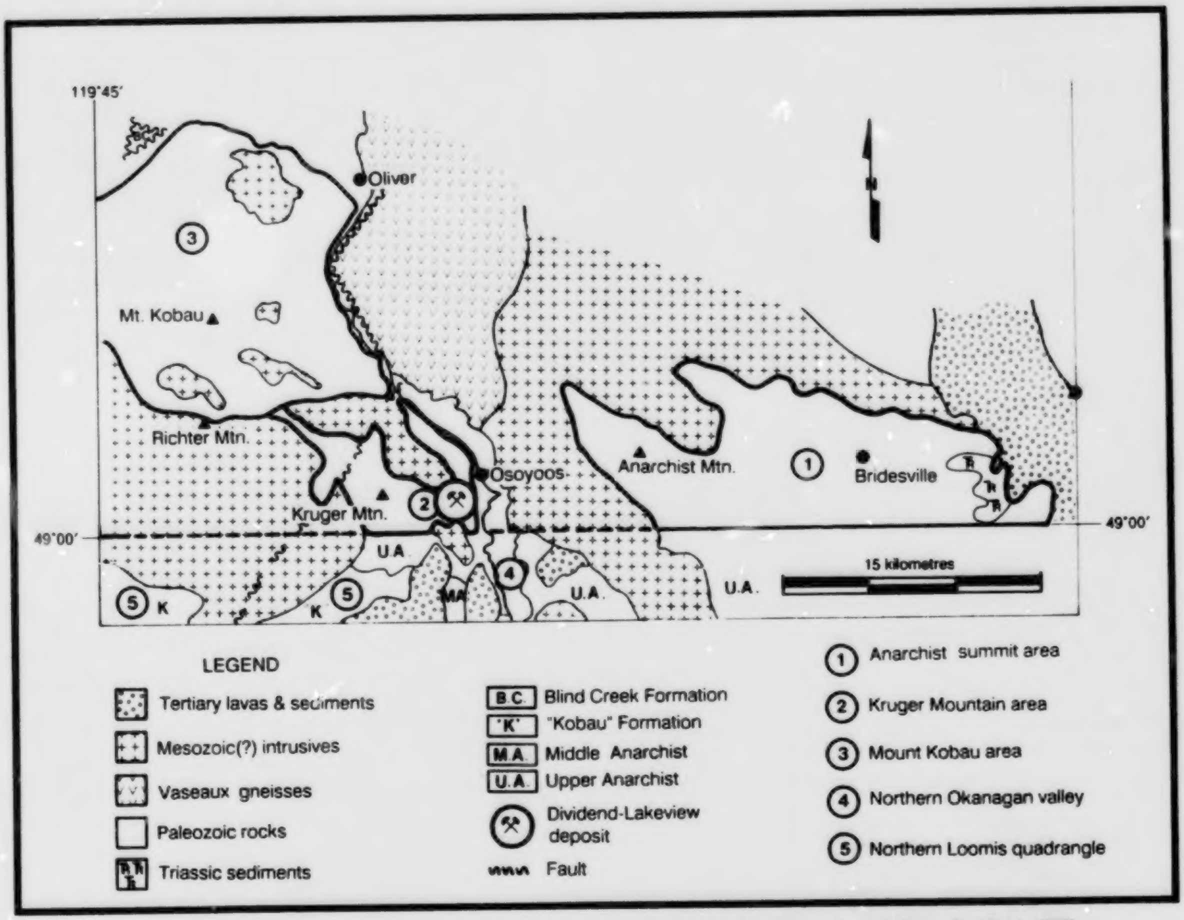

119°45′
Oliver
3
Mt. Kobau
Richter Mtn.
Osoyoos
Anarchist Mtn.
1
Bridesville
2
Kruger Mtn.
49°00′
49°00′
U.A
4
5
K
K
5
MA
U.A.
U.A.
15 kilometres
LEGEND
Tertiary lavas & sediments
Mesozoic(?) intrusives
Vaseaux gneisses
Paleozoic rocks
Triassic sediments
B.C. Blind Creek Formation
'K' "Kobau" Formation
M.A. Middle Anarchist
U.A. Upper Anarchist
Dividend-Lakeview deposit
Fault
1 Anarchist summit area
2 Kruger Mountain area
3 Mount Kobau area
4 Northern Okanagan valley
5 Northern Loomis quadrangle

Figure 22. General geology of the Osoyoos district showing location of the Dividend-Lakeview deposit (from Peatfield, 1978).

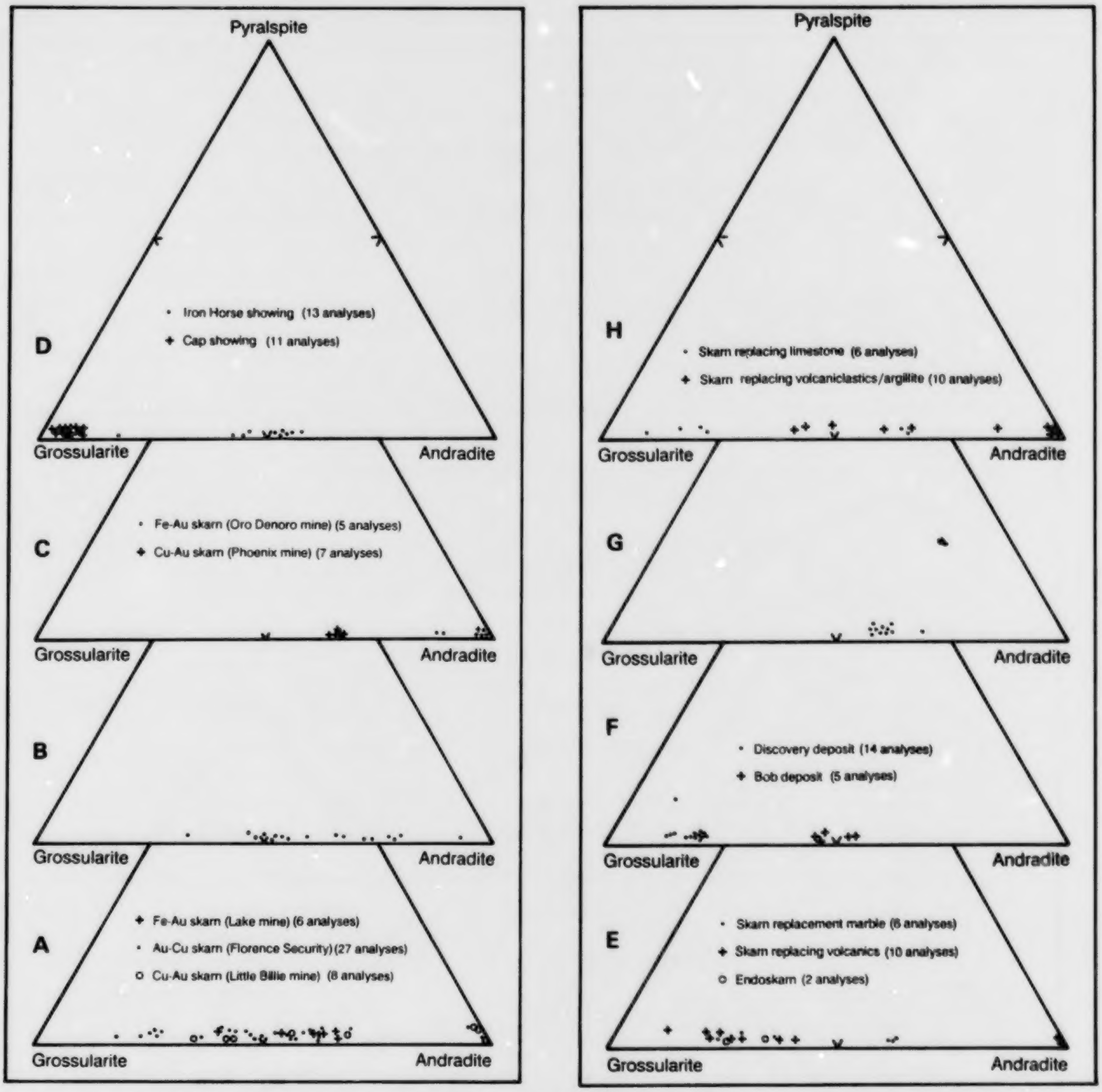


Figure 23. Composition of garnets from some PME skarns in British Columbia. (Analyses by A.D. Ettlinger at Washington State University, U.S.A.)

A = Texada Island camp (41 analyses).
B = Dividend-Lakeview mine (17 analyses).
C = Greenwood camp (12 analyses).
D = Oka claims (24 analyses).
E = Merry Widow mine (18 analyses).
F = Banks Island (19 analyses).
G = TP claims (11 analyses).
H = JTKL claims, Nanaimo Lakes (16 analyses).

Garnet, amphibole and epidote with pyrite, pyrrhotite, magnetite and locally abundant arsenopyrite replaces metavolcanic rocks and thinly interbedded marbles that belong either to the Permian Anarchist Group or the Triassic Kobau Group (Cockfield, 1935; McKechnie, 1964).

The mine area is underlain by micaceous quartzite, mica and chlorite schist, limestone and greenstone; all rocks, other than the limestones, are sheared and exhibit schistose textures. The limestones form discontinuous lenses which have been totally recrystallized near the ore-bearing horizons. Within the property there are also andesitic to basaltic flows which are propylitically altered to epidote, calcite, chlorite and pyrite, and locally replaced by skarn.

Intrusive rocks outcropping on the property are part of the Jurassic-Cretaceous Nelson batholith of quartz diorite to diorite composition and generally composed of medium-grained subhedral biotite, hornblende and plagioclase phenocrysts in a groundmass of anhedral quartz, plagioclase and potassium feldspar. Skarn-altered dioritic rocks of uncertain status have been identified in the mine open pit (G.L. Dawson, personal communication, 1988).

SKARN MINERALIZATION

At the main Dividend-Lakeview mine workings, the greenstones contain a 1 to 3-metre-thick marble lens; the greenstones exhibit a weak to moderate schistose foliation, and are overprinted by an epidote stockwork and intense chlorite-carbonate alteration. Quartz-calcite veining with pyrite, chalcopyrite and minor malachite and azurite cuts the sheared volcanics and extends beyond the area overprinted by skarn alteration.

Skarn mineralization consists of finely banded to massive pyrrhotite, pyrite, chalcopyrite and arsenopyrite, which preferentially replaces marble. Skarn in the surrounding greenstone contains garnet, epidote, chlorite, amphibole, quartz, calcite and magnetite. Massive magnetite with minor chalcopyrite occurs in a mine pillar at the limestone-volcanic contact, where it is associated with deep brown, coarse-grained garnet. Elsewhere, the garnet is pale amber in colour and fine to medium grained. As seen in thin section, garnet generally forms euhedral, anisotropic grains with concentric growth zones. Fractures filled with a fine-grained intergrowth of iron oxide and quartz form a network cutting the garnets.

Two varieties of amphibole occur with the garnet. A deep green pleochroic amphibole is the most abundant; preliminary analyses indicate it to be a chlorine-rich ferrohastingsite which is also observed at other gold-enriched skarns in British Columbia (Ettlinger and Ray, 1988). The second type forms colourless to pale green needles and is actinolitic in composition.

Other minerals present in variable amounts include chlorite, epidote, calcite, quartz, sericite, sphene and clay. Opaque minerals identified are magnetite, ilmenite, pyrrhotite, pyrite, marcasite, arsenopyrite, chalcopyrite, hedleyite, and native gold and bismuth. Electron microprobe analyses of garnets from the mine area identify them as

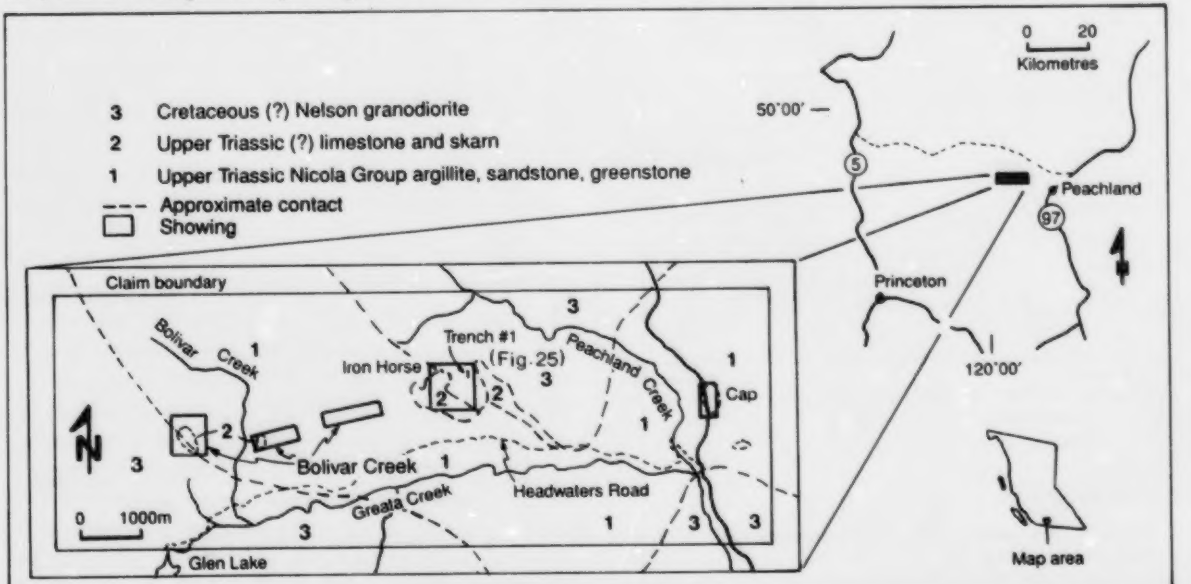

3 Cretaceous (?) Nelson granodiorite
2 Upper Triassic (?) limestone and skarn
1 Upper Triassic Nicola Group argillite, sandstone, greenstone
--- Approximate contact
Showing
0 20
Kilometres
50°00′
5
Peachland
97
Princeton
120°00′
Map area
Claim boundary
Bolivar Creek
Trench #1
(Fig. 25)
Iron Horse
Peachland Creek
Cap
Bolivar Creek
Greata Creek
Headwaters Road
0 1000m
Glen Lake
N
1
2
3

Figure 24. General geology and location of the Oka claims, Peachland district. Geology from Fairfield Minerals Ltd., unpublished company reports.

grandites, ranging from Ad 32 to Ad 93 mole per cent (Figure 23B). Compositional variations within individual garnet grains are discussed later in this report.

Skarn mineralization can be traced for a considerable distance along a westerly strike from the Dividend-Lakeview pit. Several small exploration pits expose garnet-epidote skarn with disseminated pyrrhotite, arsenopyrite, pyrite and chalcopyrite. This linear trend of mineralization, together with intense shearing of the volcanics in the mine area, suggests a structural control to skarn mineralization.

OKA CLAIM GROUP
(MINFILE 082ENW025)

The Oka occurrence is situated along Greata Creek approximately 15 kilometres west-northwest of Peachland (Figure 24). PME-skarn mineralization outcrops at the Bolivar, Iron Horse and Cap showings within the claim block. The stratigraphic sequence and intrusive suites resemble the lithologies observed at the Nickel Plate and French mines in the Hedley district, 50 kilometres to the south.

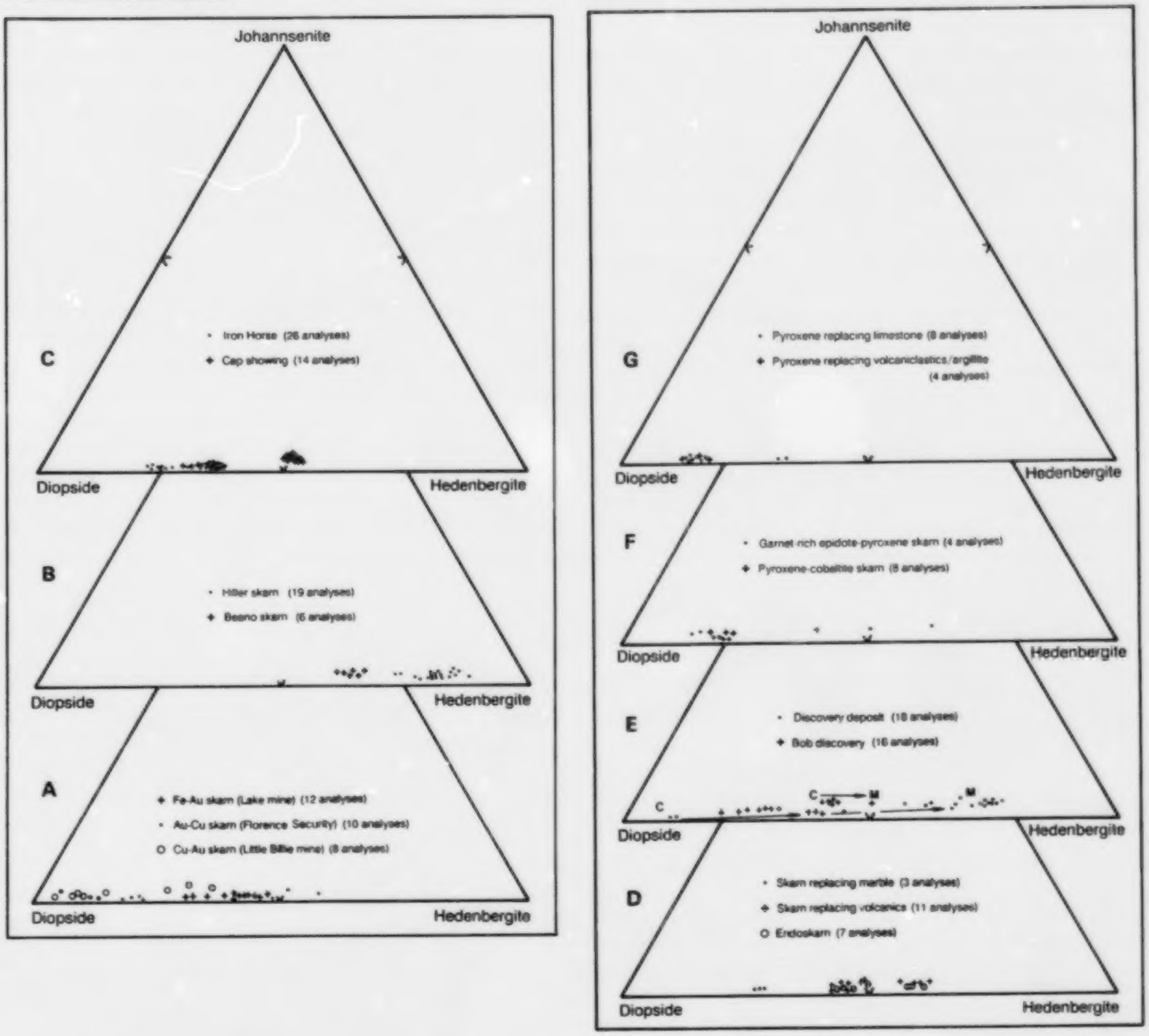


Figure 25. Composition of pyroxenes from some PME skarns in British Columbia. (Analyses by A.D. Ettlinger at Washington State University, U.S.A.)

A = Texada Island camp (30 analyses).
B = Zeballos camp (25 analyses).
C = Oka claims (40 analyses).
D = Merry Widow mine (21 analyses).
E = Banks Island (34 analyses).
F = TP claims (12 analyses).
G = JTKL claims, Nanaimo Lakes (12 analyses).
Arrows in Figure 25E indicate direction of crystal growth from cores (C) to margins (M).

The district was mapped by Little (1961) and most of the area is underlain by granodioritic and dioritic rocks that are presumed to belong to the Jurassic-Cretaceous Nelson batholith. Upper Triassic Nicola Group rocks comprising crystal tuff, argillite, siltstone, limestone and breccia form roof pendants within the batholith.

SKARN MINERALIZATION

Two distinct areas of skarn alteration were sampled within the claim group. Mineralization in the Iron Horse area (Figure 24) is hosted by Nicola Group limestones and minor cherty rocks which have been recrystallized to a grey-coloured, medium-grained marble and dark green hornfels, respectively. These rocks are intruded by small stocks, dikes and sills of variable composition. Classification based on normative mineralogy indicates that both granitic and quartz dioritic intrusions are present (*see* Figure 39C) but it is uncertain which phase is directly responsible for skarn formation; limited whole-rock geochemical data suggest that rocks adjacent to the mineralization, which were previously described as biotite quartz diorite are, in fact, granitic in composition. This intrusive phase, which contains abundant endoskarn (Ettlinger and Ray, 1988), is finer grained and contains more biotite and hornblende than presumed later granites in the same area.

Several areas of skarn and sulphide mineralization have been exposed by surface stripping at the Iron Horse showing. Skarn replaces both intrusive rock and marble which also contains minor interbedded cherty sediments. The endoskarn consists of medium green pyroxene, with variable amounts of sphene, garnet, tremolite and dark green epidote. In thin section, coarse subhedral pyroxene ranging in composition from Hd 16 to Hd 35 mole per cent (Figure 25C), together with sphene, apatite and minor garnet, is surrounded by a groundmass of sericite and clay. Late veinlets of prehnite, pyrite and lesser chalcopyrite crosscut and replace the pyroxene skarn.

In the marble, adjacent to the intrusion, skarn consists of medium brown garnet, pale green pyroxene, quartz and calcite. Away from the marble-intrusive contact, a zone of fine-grained wollastonite and light brown garnet is locally present. The garnet in the exoskarn varies in composition from Ad 7 to Ad 56 mole per cent (Figure 23D) and forms isotropic granular masses that have commonly undergone retrograde alteration to carbonate, quartz and epidote.

Sulphides, comprising pyrite, pyrrhotite, arsenopyrite and chalcopyrite, occur at the skarn front, immediately adjacent to the marble. The sulphides, together with fine-grained disseminated quartz and pyroxene, form irregularly shaped massive pods, generally less than 20 metres across. Minor amounts of inter-

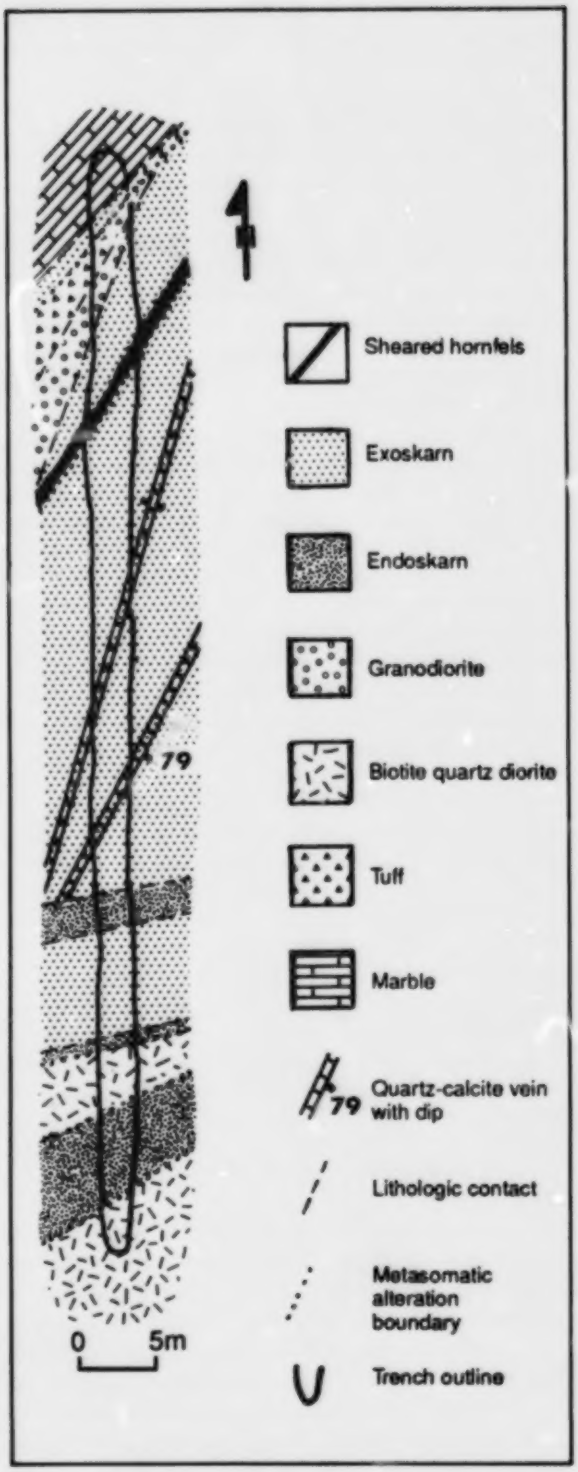


Figure 26. Geology of Trench No. 1, Iron Horse showing, Oka claims. (Geology by A.D. Ettlinger.)

bedded tuffaceous or cherty units within the sulphide pods are hornfelsed to a fine-grained dark green pyroxene-rich rock.

The above pattern can be seen in Trench 1 (Figure 26) where quartz diorite intrudes limestone and forms skarn. Remnant patches of the quartz diorite are contained within the coarse-grained skarn which consists of dark brown garnet, green diopside and pale yellowish white grains of sphene. Further from the intrusion the calc-silicate minerals become paler coloured and garnet-pyroxene-wollastonite skarn crosscut by barren quartz-carbonate veins becomes the dominant rock type. A coarse-grained granitic dike, which apparently crosscuts the skarn, occurs at the north end of the trench near the skarn-marble contact.

In contrast to the Iron Horse showing, skarn formation in the Cap area, approximately 4 kilometres to the east, is hosted by a mixture of marble, argillite, siltstone, tuff and limestone breccia. Garnet-pyroxene skarn development is limited in extent, occurring as irregular stratiform lenses and stringers that replace marble and argillite. Pyroxene and biotite hornfelsing of the clastic rocks occurs over a wide area around the showing but no source intrusive rocks outcrop in the immediate vicinity.

Thin-section studies of samples from the Cap showing reveal the presence of two types of garnet within skarn replacing the siltstone protolith. The earlier variety forms fine-grained, anhedral isotropic grains that poikalitically enclose pyroxene. The second, later, garnet is associated with pyrrhotite in veinlets which crosscut earlier pyroxene. All garnets analysed are grossularitic in composition (Figure 23D). This consistent garnet composition at the Cap showing is in contrast to the garnets at the Iron Horse showing which vary from Ad 6 to Ad 56 mole per cent in composition (Figure 23D).

Fine-grained pyroxene hornfels in the siltstone protolith ranges in composition from Hd 25 to Hd 34 mole per cent. A later metasomatic pyroxene is present as fine euhedral grains which form irregular clots enclosed by garnet. This later pyroxene is more iron rich than the earlier hornfelsic pyroxene and generally ranges in composition from Hd 48 to Hd 53 mole per cent (Figure 25C).

The controls to the primary gold mineralization on the Oka property are uncertain; in addition to the primary skarn-related gold, some secondary enrichment may be present along late fractures. Gold assays in chip samples "greater than 1 gram per tonne" are reported by Fairfield Minerals Ltd. from diorite and massive sulphides, although not all the sulphide pods are gold rich. Anomalous gold values also occur in the footwall of a northeasterly striking reverse fault which crosscuts one of the sulphide pods.

TP CLAIMS
(MINFILE 104M048, 050)

Gold-cobalt-arsenopyrite mineralization occurs in skarn on the southwest flank of Teepee Peak, 50 kilometres west of Atlin. This occurrence is unusual in that cobalite is the main sulphide present, and the skarn is developed in high-grade metamorphic rocks.

Mineralization is hosted by pre-Triassic gneisses and schists of the Yukon Group close to their contact with a large, composite hornblendite-diorite intrusion (M. Mihalynuk, personal communication, 1987). Exploration work completed in 1983 outlined two northwesterly trending fracture zones with localized gold and cobaltite-erythrite mineralization. The main zone measures approximately 15 by 200 metres at surface and consists of four skarn types (T.G. Schroeter, personal communication, 1987): magnetite-rich skarn with minor calcite, garnet and amphibole; calc-silicate rich skarn with garnet, epidote and calcite; amphibole-rich skarn which hosts most of the fracture-controlled mineralization; and marble-rich skarn.

In outcrop, the veins of skarn have centres of dark brown garnet which pass outward to light brown garnet and finally pale green epidote; these veins cut finely banded feldspathic gneiss. In thin section, the garnets are seen forming euhedral anisotropic grains and are partially replaced by green pleochroic amphibole. Compositionally they vary from Ad 56 to Ad 67 mole per cent with up to 4.5 mole per cent pyralspite (Figure 23G). Minor fine-grained granular pyroxene ranging in composition from Hd 10 to Hd 36 mole per cent (Figure 25F) is associated with the garnet-rich portions.

Extensive float of cobaltite and erythrite-rich pyroxene skarn occurs below the main trenched area. The pyroxene forms fibrous white to light grey crystals less than 1 millimetre long. It is diopsidic in composition (Figure 25F) and is commonly cut by fine fractures containing erythrite. Chlorite replaces the pyroxene along grain boundaries and cleavage planes.

The cobaltite, which contains inclusions of native bismuth and minor galena, is disseminated with arsenopyrite throughout the pyroxene skarn. A sulphide-rich sample of this pyroxene-cobaltite skarn assayed 4.2 grams gold and 33 grams silver per tonne, 0.15 per cent lead, 1.7 per cent cobalt, 2.3 per cent arsenic and 0.32 per cent bismuth. Microprobe analyses show that some native bismuth grains not enclosed by cobaltite contain up to 3.4 per cent cobalt, 6.2 per cent arsenic and 0.11 per cent tellurium as well as anomalous gold values. Chip samples from trenches across the mineralized fracture zones returned composite average assays up to 15.0 grams gold per tonne and 3.91 per cent cobalt over 3.5 metres (Lhotka and Olson, 1983).

CHAPTER 3

GEOLOGY OF SELECTED PME SKARNS IN THE OMINECA BELT

GREENWOOD CAMP (MINFILE 082ESE013 to 028, 030, 031, 034, 049, 050, 052, 062, 063, 064)

The Greenwood camp contains several styles of mineralization which result from multiple stages of intrusive activity and a complex structural history. The economic geology, stratigraphy and structural geology have been previously described by LeRoy (1912), McNaughton (1945), Seraphim (1956), Peatfield (1978), Little (1983) and Church (1986). Additional geological data has been supplied by Fyles (personal communication, 1989).

PME copper and iron-skarn mineralization occurs at several locations in the district. The Phoenix, Greyhound, Mother Lode, Oro Denoro, Emma and Marshall skarn deposits (Figure 27) produced a total of approximately 36 tonnes of gold, 217 tonnes of silver and 270 000 tonnes of copper from 31.8 million tonnes of ore.

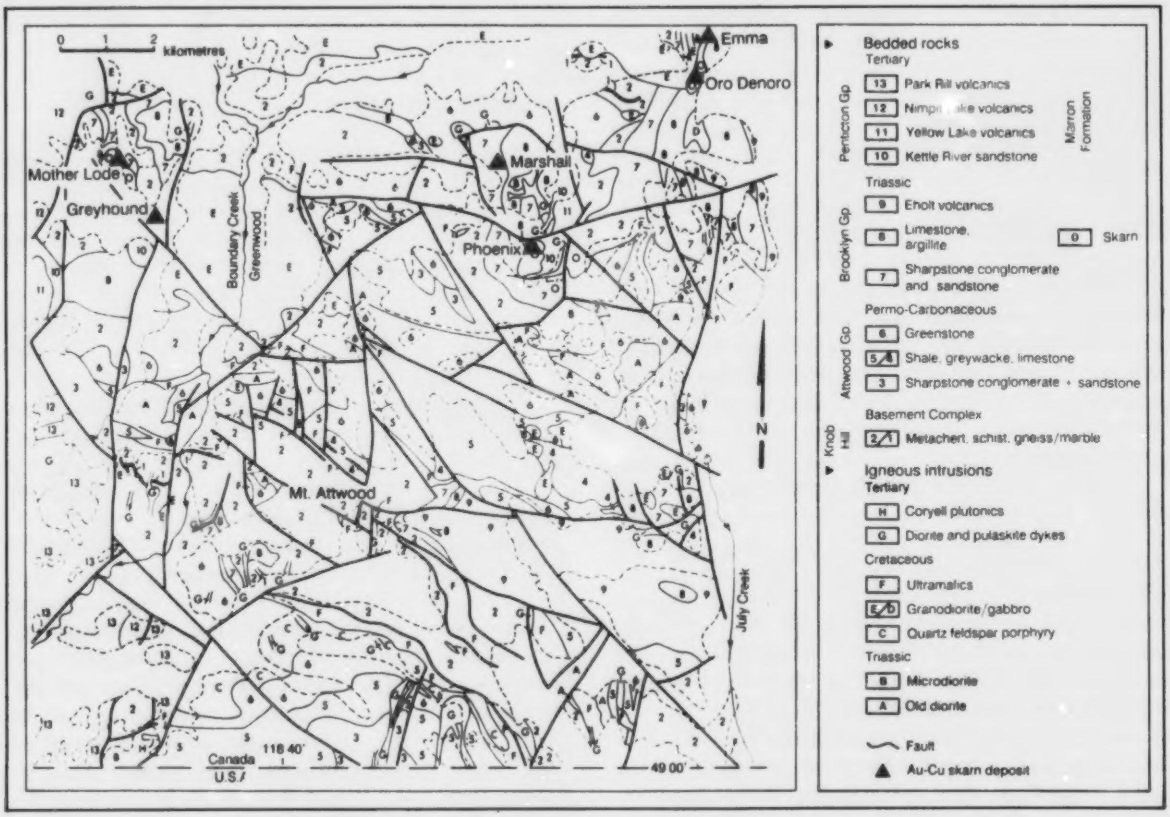

0 1 2 kilometres
Emma
Oro Denoro
Marshall
Mother Lode
Greyhound
Phoenix
Mt. Attwood
Boundary Creek
Greenwood
July Creek
N
Canada
U.S.
118 40'
49 00'
Bedded rocks
Tertiary
Penticton Gp
13 Park Rill volcanics
12 Nimpit Lake volcanics
11 Yellow Lake volcanics
10 Kettle River sandstone
Marron Formation
Triassic
Brooklyn Gp
9 Eholt volcanics
8 Limestone, argillite
7 Sharpstone conglomerate and sandstone
0 Skarn
Permo-Carbonaceous
Attwood Gp
6 Greenstone
5/4 Shale, greywacke, limestone
3 Sharpstone conglomerate + sandstone
Basement Complex
Knob Hill
2/1 Metachert, schist, gneiss/marble
Igneous intrusions
Tertiary
H Coryell plutonics
G Diorite and pulaskite dykes
Cretaceous
F Ultramafics
E/D Granodiorite/gabbro
C Quartz feldspar porphyry
Triassic
B Microdiorite
A Old diorite
Fault
Au-Cu skarn deposit

Figure 27. Geology and location of skarn deposits in the Greenwood camp (after Church, 1986).

DISTRICT GEOLOGY

The skarn deposits are associated with the late Paleozoic Knob Hill Group and the unconformably overlying rocks of the Triassic Brooklyn Formation. The Knob Hill Group, as described by Little (1983), consists of massive chert, greenstone and amphibolite with minor pods and thin, widely scattered beds of limestone and argillite. The Brooklyn Formation includes thick units of sharpstone conglomerate and limestone, as well as thinner beds of siltstone, sandstone and calcareous chert-pebble conglomerate. The sharpstone conglomerate, originally considered to be silicified argillite or jasperoid (Brock, 1903; LeRoy, 1912; McNaughton, 1945), was first recognized as a clastic rock by Seraphim (1956). It contains angular fragments of chert and minor limestone, greenstone and jasper clasts set in a fine-grained chert, calcite and chlorite-rich matrix. The conglomerate is massive near its base and commonly bedded near its top, with numerous interbeds of sandstone, shale, siltstone and minor limestone. At the type locality, close to the Phoenix and Marshall deposits, a basal sharpstone conglomerate up to 600 metres thick grades upwards into interbedded sandstone, siltstone and calcareous rocks. The conglomerate is overlain by the Brooklyn limestone which reaches 350 metres in thickness and comprises limestone and minor siltstone. This unit thins northwards and rapidly dies out to the south. It is overlain in turn by another sharpstone conglomerate, called the upper sharpstone, which passes northwards into siltstone. To the south, in the Phoenix mine area, it joins the lower sharpstone which suggests that these two sharpstone units were deposited as coalescing fans. The upper sharpstone is overlain by the Stemwinder limestone, a lenticular unit of limestone and calcareous breccia which passes upwards into volcanic rocks. The succession is intruded by irregular dikes of microdiorite from which Church (1986) obtained a K:Ar date of 206±8 Ma; these dikes are probably feeders to the volcanics which overlie the Stemwinder limestone.

Regionally the Knob Hill Group trends east to southeast and dips moderately north, whereas the Brooklyn Formation strikes north to northeast and dips steply east. The rocks are broadly folded and have been affected by low grade regional metamorphism. They are truncated to the north by granodiorite of the Wallace Creek batholith, the southern margin of which has irregular apophyses and satellite intrusions that have thermally metamorphosed the country rocks.

The Mesozoic rocks are unconformably overlain by Tertiary volcanic sandstones and conglomerate of the Kettle River Formation and trachyitic to andesitic flows of the Marron Formation (Monger, 1968). These rocks belong to the Penticton Group (Church, 1986), and in places they unconformably overlie the pre-Tertiary intrusions and Paleozoic schists and gneisses.

Eight intrusive phases have been identified by Church (1986). The major intrusive event is represented by the Cretaceous Greenwood stock and Wallace Creek batholith (143±5 Ma, K:Ar on biotite, Church, 1986) which are considered to be part of the Nelson plutonic suite and genetically related to economic skarn development in the Greenwood camp. Church (1986) reports a normalized oxide composition for the Wallace Creek batholith of: 66.77 per cent SiO_2, 15.89 per cent Al_2O_3, 4.88 per cent CaO, 3.33 per cent Na_2O, 2.30 per cent K_2O, 2.30 per cent FeO, 2.10 per cent Fe_2O_3, 1.82 per cent MgO, 0.50 per cent TiO_2 and 0.11 per cent MnO. The mineral norms based on this composition and that of an apophysis at the Oro Denoro mine (*see* Church, 1986) indicate they are granodioritic to tonolitic in nature.

Earlier intrusive activity involved small diorite, microdiorite, quartz feldspar porphyry and gabbro bodies that show varying degrees of alteration, but are not apparently associated with economic skarn mineralization. Tertiary intrusions include many dikes, sills and irregular bodies of monzodiorite and other alkalic rocks. These intrusions are associated with several styles of mineralization throughout the district.

SKARN MINERALIZATION

Within the Greenwood district, both PME copper and iron-skarn mineralization is present. The former occurs at the Phoenix, Motherlode, Marshall and Greyhound deposits, while PME iron-skarn mineralization is present at the Oro Denoro and Emma deposits. In both skarn types, garnet, epidote and amphibole are the primary calc-silicate minerals present. The PME copper skarns contain chalcopyrite, pyrite, and specular and earthy hematite, with minor magnetite and pyrrhotite as the primary opaque phases, while the PME iron skarns contain magnetite, pyrite and hematite with local chalcopyrite-rich zones.

The formation of skarn in the district appears to be preferentially controlled by the contact between Brooklyn limestone and underlying sharpstone and siltstone beds. Skarn mineralization is widespread in the Brooklyn Formation and is found rarely in calcareous members of the Knob Hill Group and other late Paleozoic formations. The largest and most productive PME copper skarns are in the lower part of the Brooklyn Formation, either in the transition zone between the lower sharpstone and the Brooklyn limestone, or within the Brooklyn limestone itself. Small copper and iron-skarn deposits occur at similar sharpstone-limestone transition zones in the higher parts of the Brooklyn Formation (Seraphim, 1956).

The protolith of the skarn exposed in the walls of the Phoenix pit is believed to be mainly sharpstone conglomerate, although the original textures are hard to recognize because of the extensive alteration. The Brooklyn and Stemwinder limestone members occur approximately 0.5 kilometre north of the pit and trend southwards into the filled parts of the Phoenix mine. The bulk of the mined copper-gold skarn was probably hosted in sharpstone conglomerate, calcareous siltstone and limestone members of the Brooklyn Formation.

Within the Phoenix mine, sharpstone conglomerate contains angular chert clasts and greenstone fragments set in a sandy, chloritic matrix. Dark brown garnet, amphibole, epidote and chlorite are the primary skarn minerals replacing both the matrix and clasts. Chalcopyrite and pyrite are the most abundant sulphides and occur either as disseminations in the massive garnet skarn or as vein fillings with calcite and specular hematite that crosscut the skarn.

Garnet crystals in the pit are pale brown coloured and generally anisotropic in thin section. They are commonly concentrically zoned, with some grains exhibiting yellow isotropic cores. Electron microprobe analyses of garnets from the Greenwood camp are given in Figure 23C. Garnet compositions from the Phoenix mine range from Ad 62 to Ad 100 mole per cent; the isotropic cores are pure andradite, while anisotropic rims are more grossularitic.

Chlorite occurs as a secondary constituent replacing garnet along fractures and as granular masses in calcite-quartz veins. Carbonate occurs both in the veins and as a remnant marble matrix to garnet. Three episodes of quartz are seen: as an irregular selvage between calcite and garnet at the marble front, with chlorite resulting from replacement of garnet, and with calcite in late veins.

To aid in grade control during mining, Sinclair and Percy (1969) studied the relationship between precious metals and the sulphide and calc-silicate content of the ore. Multiple regression analyses show that gold values tend to be highest where chalcopyrite and, to a lesser extent, pyrite are abundant. The presence of gold, however, does not appear to be significantly affected by the presence of calc-silicate minerals. Silver was found to be even more strongly controlled by the presence of the sulphides and also independent of other skarn minerals.

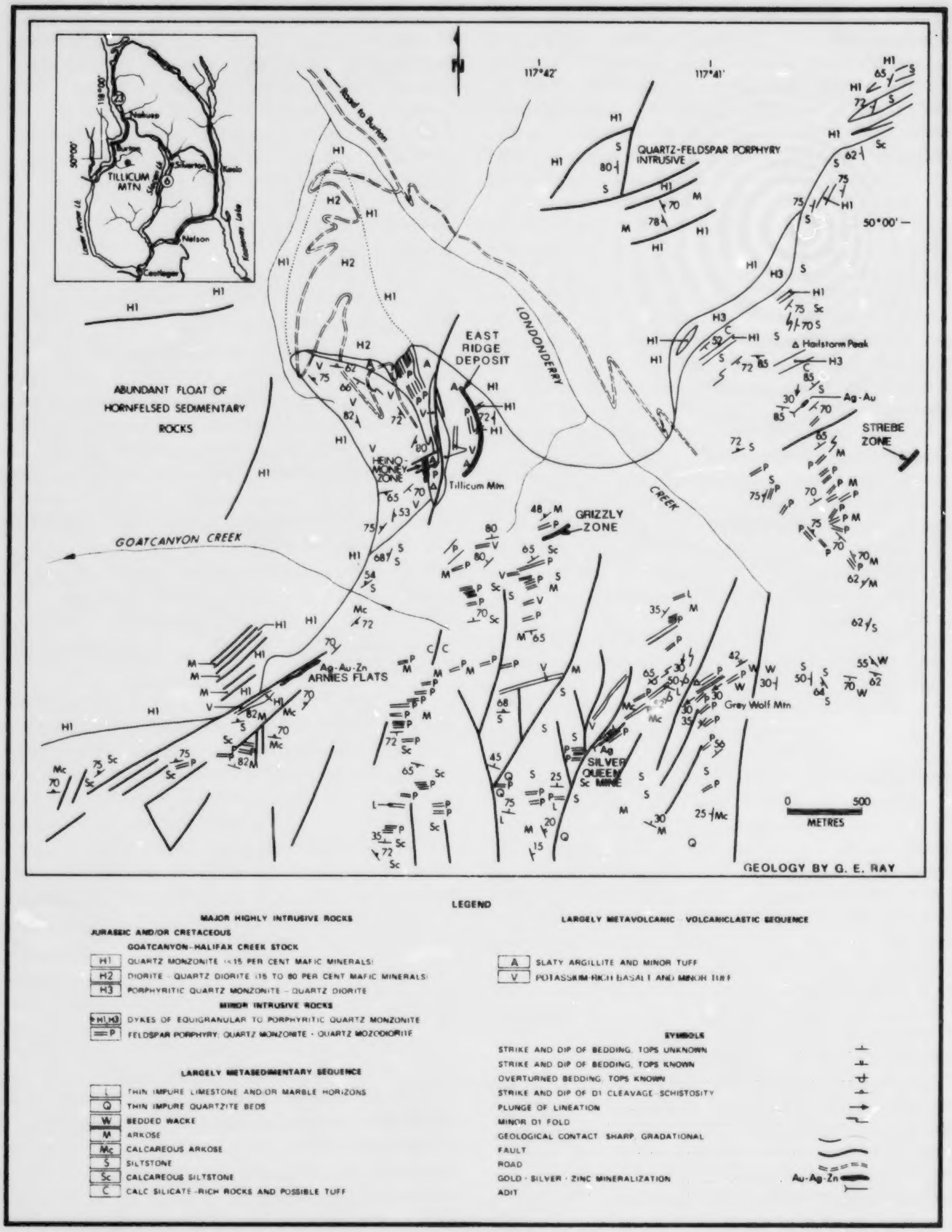
McNaughton (1945) suggested that the skarn mineralization in the Phoenix area is the result of a deep, underlying intrusion. Recent detailed mapping of the Phoenix mine by Washington State University has identified mineralogic zoning, possibly indicating an intrusive source outside the pit limit (D. Still, personal communication, 1988). A zone of massive garnet, specular hematite and chalcopyrite occurs in the southern and lowermost accessible benches of the mine. Towards the north and along the upper benches, this garnet-rich zone grades into a zone consisting of abundant epidote, amphibole and chlorite, which may represent retrograde replacement of the massive garnet. Farther north, near the Stemwinder and Brooklyn mines, skarn minerals are less abundant and limestone is present. This pattern suggests an unexposed intrusive source may lie south of the present pit limit, the massive garnet representing mineralization proximal to the intrusion. The epidote-amphibole-chlorite assemblage grading into limestone in the Stemwinder and Brooklyn mines may represent more distal low-temperature retrograde alteration developed at the marble front.

The copper-skarn mineralization at the Motherlode pit occurs in the same member of the Brooklyn Formation as the skarns at the Phoenix mine. The formation, which strikes northwards and dips steeply east, also includes a lower sharpstone conglomerate overlain by skarn-altered siltstone and lenses of Brooklyn limestone and an overlying fine-grained sharpstone. In addition a large dike of weakly skarn-altered limestone and chert-pebble conglomerate are present (Olson and Sutherland Brown, 1968). The limestone is mostly altered to garnet skarn, but banded garnet-epidote-actinolite skarn is also common. The original chert pebbles are replaced by recrystallized strained quartz, while the volcanic fragments are altered to feldspar-muscovite-calcite aggregates. Some of the calcite-rich matrix and volcanic fragments are partially replaced by epidote, garnet, magnetite and minor sulphides.

Skarn at the Oro Denoro mine consists of massive reddish brown garnet and magnetite with coarse megacrystic calcite. Later amphibole and chlorite veinlets replace the garnet. Skarn is localized in limestone and sharpstone conglomerate beds at a contact with Nelson granodiorite. At the north end of the main workings, endoskarn occurs in the granodiorite. It is characterized by massive green epidote which replaces remnant skeletal brown garnet. Minor fibrous pale green amphibole occurs with the epidote and is also an alteration product of the garnet.

Garnet compositions from the Oro Denoro mine are presented in Figure 23C. They are slightly more restricted in composition than the Phoenix mine garnets, ranging from Ad 85 to Ad 100 mole per cent, but they exhibit the same pattern of variation from core to rim.

The Emma deposit lies approximately 1.5 kilometres north of the Oro Denoro mine. This deposit follows the contact between the northerly striking Brooklyn limestone and underlying siltstone beds close to the margin of Cretaceous granodiorite. It is not certain if the skarn deposit is genetically related to this granodiorite body. Skarn consists of reddish brown garnet, epidote and



117°42'
117°41'
50°00'
N
Road to Burton
TILLICUM MTN
Nakusp
Burton
Silverton
Kaslo
Nelson
Castlegar
Lower Arrow Lk.
Kootenay Lake
118°00'
QUARTZ-FELDSPAR PORPHYRY INTRUSIVE
EAST RIDGE DEPOSIT
LONDONDERRY CREEK
ABUNDANT FLOAT OF HORNFELSED SEDIMENTARY ROCKS
HEINO-MONEY ZONE
Tillicum Mtn
GRIZZLY ZONE
GOATCANYON CREEK
Ag-Au-Zn
ARNIES FLATS
Hailstorm Peak
Ag-Au
STREBE ZONE
Grey Wolf Mtn
Ag
SILVER QUEEN MINE
0
500
METRES
GEOLOGY BY G. E. RAY
LEGEND
MAJOR HIGHLY INTRUSIVE ROCKS
JURASSIC AND/OR CRETACEOUS
GOATCANYON-HALIFAX CREEK STOCK
H1 QUARTZ MONZONITE (<15 PER CENT MAFIC MINERALS)
H2 DIORITE - QUARTZ DIORITE (15 TO 80 PER CENT MAFIC MINERALS)
H3 PORPHYRITIC QUARTZ MONZONITE - QUARTZ DIORITE
MINOR INTRUSIVE ROCKS
H1,H3 DYKES OF EQUIGRANULAR TO PORPHYRITIC QUARTZ MONZONITE
P FELDSPAR PORPHYRY: QUARTZ MONZONITE - QUARTZ MONZODIORITE
LARGELY METASEDIMENTARY SEQUENCE
L THIN IMPURE LIMESTONE AND/OR MARBLE HORIZONS
Q THIN IMPURE QUARTZITE BEDS
W BEDDED WACKE
M ARKOSE
Mc CALCAREOUS ARKOSE
S SILTSTONE
Sc CALCAREOUS SILTSTONE
C CALC SILICATE-RICH ROCKS AND POSSIBLE TUFF
LARGELY METAVOLCANIC VOLCANICLASTIC SEQUENCE
A SLATY ARGILLITE AND MINOR TUFF
V POTASSIUM-RICH BASALT AND MINOR TUFF
SYMBOLS
STRIKE AND DIP OF BEDDING, TOPS UNKNOWN
STRIKE AND DIP OF BEDDING, TOPS KNOWN
OVERTURNED BEDDING, TOPS KNOWN
STRIKE AND DIP OF D1 CLEAVAGE SCHISTOSITY
PLUNGE OF LINEATION
MINOR D1 FOLD
GEOLOGICAL CONTACT: SHARP, GRADATIONAL
FAULT
ROAD
GOLD - SILVER - ZINC MINERALIZATION
Au-Ag-Zn
ADIT

Figure 28. Geology of Tillicum Mountain area, and location of the Heino-Money zone, East Ridge deposit and Silver Queen mine (after Ray *et al.*, 1985).

massive magnetite which is preserved in pillars in the mine.

At the Marshall deposit, approximately 1.5 kilometres northwest of the Phoenix pit (Figure 27), skarn is developed at the contact between Brooklyn limestone and an underlying siliceous siltstone. At the main showing, massive pyrrhotite with minor chalcopyrite replaces limestone, remnants of which are recrystallized to a medium-grained marble. Fine-grained, dark green amphibole occurs sporadically in the marble and adjacent hornfelsic siltstone. At one location, a small pod of pyroxene-amphibole skarn is separated from marble by a lens of massive pyrrhotite-chalcopyrite-magnetite. An outcrop of altered microdiorite occurs in the area. This deposit may represent skarn formation resulting from pre-Nelson intrusive activity.

TILLICUM MOUNTAIN CAMP

Gold and/or silver-bearing skarns are found on Tillicum and Grey Wolf mountains, approximately 30 kilometres south of Nakusp in southeastern British Columbia (Figure 28). The skarn mineralization is spatially and probably genetically related to a suite of deformed, often schistose feldspar-porphyry intrusions. These intrusions have subalkalic, calc-alkaline affinities, and are quartz monzonite to quartz monzodiorite in composition. They intrude a highly deformed, metamorphosed, volcano-sedimentary succession that Ray and Spence (1986) correlate with the Lower Jurassic Rossland Group.

The skarns are divisible into gold-rich and silver-rich types (McClintock and Roberts, 1984; Ray *et al.*, 1985). The former is represented by auriferous skarn mineralization at several separate localities, including the Heino-Money and Grizzly zones, the East Ridge deposit and the recently discovered Strebe showing (Figure 28) The Heino-Money zone and East Ridge deposit are situated on the northwest flank of Tillicum Mountain, while the Strebe prospect lies approximately 3 kilometres to the east. The mineralization at the defunct Silver Queen mine, situated 900 metres southwest of Grey Wolf Mountain (Figure 28), is an example of a silver-rich skarn.

Esperanza Exploration Ltd. has been actively exploring and developing the camp. Proven reserves for the Heino-Money zone are 50 000 tonnes grading 35 grams gold per tonne (J. Brock, personal communication, 1988). Estimated reserves for the East Ridge deposit are in the order of 2 million tonnes grading 6.9 grams gold per tonne, with a drill-indicated higher grade core comprising 344 000 tonnes grading 10.3 grams gold per tonne.

GENERAL GEOLOGY

The supracrustal rocks hosting the skarn-related mineralization form part of a predominantly metasedimentary succession within the highly deformed, easterly trending Nemo Lakes belt (Parrish, 1981). This belt represents a roof pendant 5 kilometres wide, bounded on the north and west by the Goatcanyon-Halifax Creek stock (Figure 28) of Jurassic and/or Cretaceous age (Hyndman, 1968), and on the south by the Nemo Lakes quartz monzonite stock of Eocene age (Parrish, 1981).

The sedimentary succession in the Tillicum Mountain area is dominated by metamorphosed siltstone, calcareous siltstone, arkose and wacke, with lesser amounts of mafic volcanic rock, tuff, argillite, impure carbonate and marble layers. No marker horizons are recognized in the succession, which exhibits rapid lateral and vertical changes in lithology. Despite the deformation and metamorphism, some sedimentary structures, including grading and crossbedding, are locally preserved. The supracrustal rocks underwent a post-Early Jurassic phase of regional metamorphism and folding (Hyndman, 1968; Parrish, 1981) that predates the Middle to Late Jurassic intrusion of the granitoid stocks (Read and Wheeler, 1976). This resulted in sillimanite-grade metamorphism throughout most of the Nemo Lakes belt (Parrish, 1981); however, the metamorphic grade was probably lower around Tillicum Mountain and resulted in the formation of biotite, muscovite, chlorite and amphibole. In addition to the regional metamorphism, the rocks were locally subjected to two episodes of contact metamorphism. The first is related to the swarms of feldspar porphyry sills and the associated skarn alteration. The sills were originally described as quartz diorite to diorite (McClintock and Roberts, 1984; Ray *et al.*, 1985), although normative plots now suggest they are mostly of quartz monzonite to quartz monzodiorite composition (Figure 39B). They were intruded during a period of deformation, and are apparently related to the gold and silver-bearing skarns in the district (Roberts and McClintock, 1984; Ray *et al.*, 1985). The second hornfelsing is related to intrusion of the large granitoid stocks and postdates the regional deformation.

Three generations of biotite crystallization are recognized in the area. The first is a schistose, black biotite which is widespread and related to the regional metamorphism. The second is characterized by a distinct pinkish brown biotite which is locally developed, and is believed to form part of the skarn alteration at the Heino-Money zone and elsewhere. The youngest episode of biotite

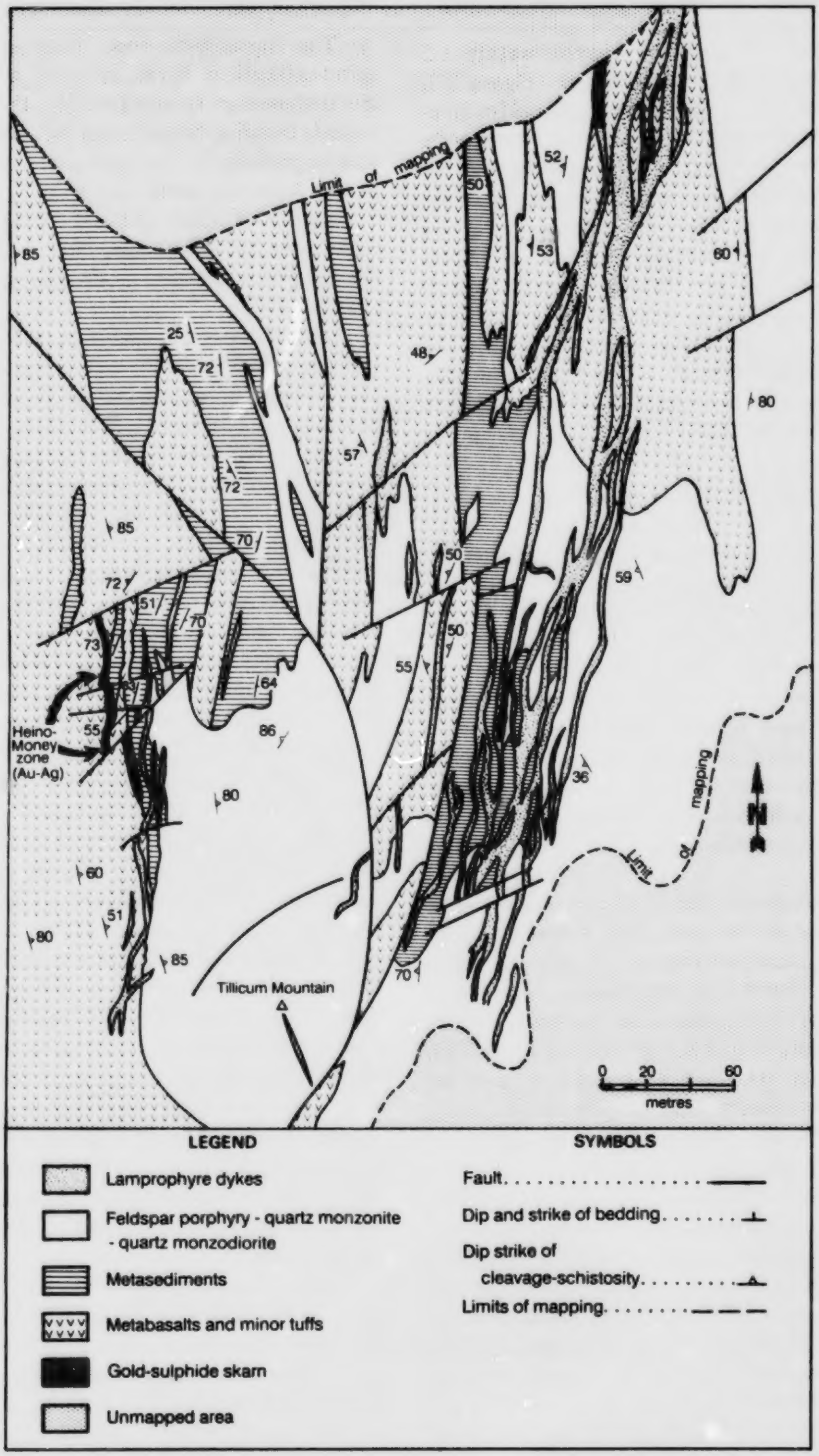

Limit of mapping
52
50
53
60
85
25
72
48
80
57
72
85
70
72
51
70
50
59
73
50
55
64
86
55
Heino-Money zone (Au-Ag)
80
36
Limit of mapping
N
60
51
80
85
70
Tillicum Mountain
0 20 60
metres
LEGEND
Lamprophyre dykes
Feldspar porphyry - quartz monzonite - quartz monzodiorite
Metasediments
Metabasalts and minor tuffs
Gold-sulphide skarn
Unmapped area
SYMBOLS
Fault
Dip and strike of bedding
Dip strike of cleavage-schistosity
Limits of mapping

Figure 29. Geology of the Heino-Money zone area, Tillicum Mountain camp. (Geology after W. Roberts and J. McClintock, Esperanza Exploration Ltd., unpublished reports.)

growth is found in the hornfelsic aureoles adjacent to the Goatcanyon-Halifax Creek and Nemo Lakes stocks.

The age, stratigraphy and structure of the supracrustal rocks at Tillicum Mountain have been controversial. Little (1960) included them in the Triassic to Early Jurassic(?) Slocan and Lower Jurassic Rossland groups, while Hyndman (1968) split the section, correlating the basic volcanic rocks on the northwestern slopes of Tillicum Mountain with the Triassic Kaslo Group, and the remaining metasedimentary rocks with the Pennsylvanian to Triassic Milford Group. However, based on the geochemistry of the volcanic rocks, which represent basaltic arc shoshonites, Ray and Spence (1986) concluded that the volcanic and volcaniclastic succession probably belongs to the Elise Formation of the Lower Jurassic Rossland Group. Ray *et al.* (1985) concluded from structural data and sedimentary top determinations that the sedimentary sequence lying south and southeast of the basaltic package (Figure 28) is younger and thus may correlate with the Hall Formation of the Rossland Group.

The feldspar porphyry intrusions related to the precious metal skarn alteration form swarms of deformed, sill-like bodies that vary from 1 to over 200 metres in width. They comprise generally leucocratic, porphyritic, medium-grained rocks that are characterized by plagioclase phenocrysts up to 1 centimetre in diameter, and locally contain abundant microcline in the groundmass. Biotite, which forms less than 10 per cent by volume, is the the most common and widespread mafic mineral; some rare, more mafic sills contain appreciable quantities of hornblende.

Igneous textures and euhedral feldspar phenocrysts are preserved in the central portions of the larger sills but the margins are generally schistose with highly flattened feldspar crystals. As seen in thin section, the margins of the oligoclase phenocrysts are frequently partially recrystallized and rimmed with small crystals of fresh, untwinned sodic plagioclase. In many areas this recrystallization process is complete, and phenocrysts are pseudomorphed by a mosaic of small plagioclase crystals, each less than 0.1 millimetre in diameter. The fine-grained matrix comprises mainly plagioclase, microcline, random to subaligned flakes of biotite, and minor to trace amounts of quartz, hornblende, chlorite and sulphides. Country rocks immediately adjacent to feldspar porphyry sills are often weakly hornfelsed.

The sills predate the large, massive, granitoid Jurassic stocks (Hyndman, 1968; Parrish, 1981), however, the precise age of their intrusion and the skarn mineralization is not known.

HEINO-MONEY ZONE
(MINFILE 082FNW234)

The Heino-Money zone is situated a few hundred metres north of Tillicum Mountain (Figures 28 and 29), where the gold-bearing, quartz-rich calc-silicate skarn alteration appears to be both structurally and stratigraphically controlled. Mineralization is mainly hosted in a thin, wedge-shaped package of highly sheared basaltic tuff, tuffaceous sedimentary rocks and calcareous argillites which is bounded to the west by metabasalts and to the east by a large, altered feldspar porphyry body (Figure 30) of quartz monzonite to quartz monzodiorite composition.

Compared to the East Ridge mineralization, where the skarn alteration envelope reaches 50 metres in thickness Figure 30), alteration at the Heino-Money zone is less well developed, although locally it has overprinted both the intrusion and supracrustal rocks. The exoskarn is a pinkish green colour with amphibole, biotite, epidote, quartz and sparse garnet and pyroxene. It is commonly strongly deformed, sheared, strongly foliated and siliceous, with abundant, parallel lenses and thin stringers of white quartz-vein material that carry visible gold and are locally crosscut by sulphides. The sporadic, pale pink, generally anhedral garnets and light green pyroxenes are found in both the endoskarn and exoskarn (including the quartz veins). The skarn assemblage includes abundant quartz and pinkish brown biotite with variable amounts of tremolite-actinolite, clinozoisite, plagioclase, clinopyroxene, garnet, hornblende, microcline, sericite and carbonate. Thin sections reveal that the biotite predates the pyroxene, which has been subsequently overgrown by the amphibole. Many weathered skarn outcrops are coated with abundant manganese oxides. Free gold occurs as fine to coarse disseminations and fracture fillings, commonly within and along walls of the quartz-sulphide veins; gold is generally associated with pyrrhotite, arsenopyrite, pyrite and sphalerite (Roberts and McClintock, 1984).

A polished section study of the Heino-Money mineralization (Northcote, 1983) showed that individual gold grains range from less than 2 microns to more than 3 millimetres in diameter. The gold occurs as plates and anhedral grains; they are generally free, but may also be intimately associated with pyrrhotite, arsenopyrite, sphalerite and pyrite-marcasite. Some pyrrhotite grains are rimmed with colloform pyrite-marcasite, while others contain small masses of hematite and graphitic material. Northcote also reported minor to trace amounts of tetrahedrite, chalcopyrite and possibly electrum.

Whole-rock and trace element analyses of samples systematically collected from a drill hole (TM82-16) that intersects the Heino-Money zone (Ray *et al.*, 1986a) indicate distinct zones of early, gold-rich and silver-poor mineralization, together with separate, slightly younger zones of silver and lead-rich, gold-poor mineralization. The latter resembles the ore at the nearby Silver Queen mine in being associated with arsenopyrite, sphalerite and argentiferous galena, as well as pyrite, pyrrhotite and trace chalcopyrite. The relatively older and more economically important gold mineralization accompanied the introduction of arsenopyrite and some sphalerite. Both the gold and silver-rich horizons at the Heino-Money zone are associated with noticeable increases in the whole-rock manganese content (up to 0.9 per cent MnO). Gold in these drill-hole samples has a

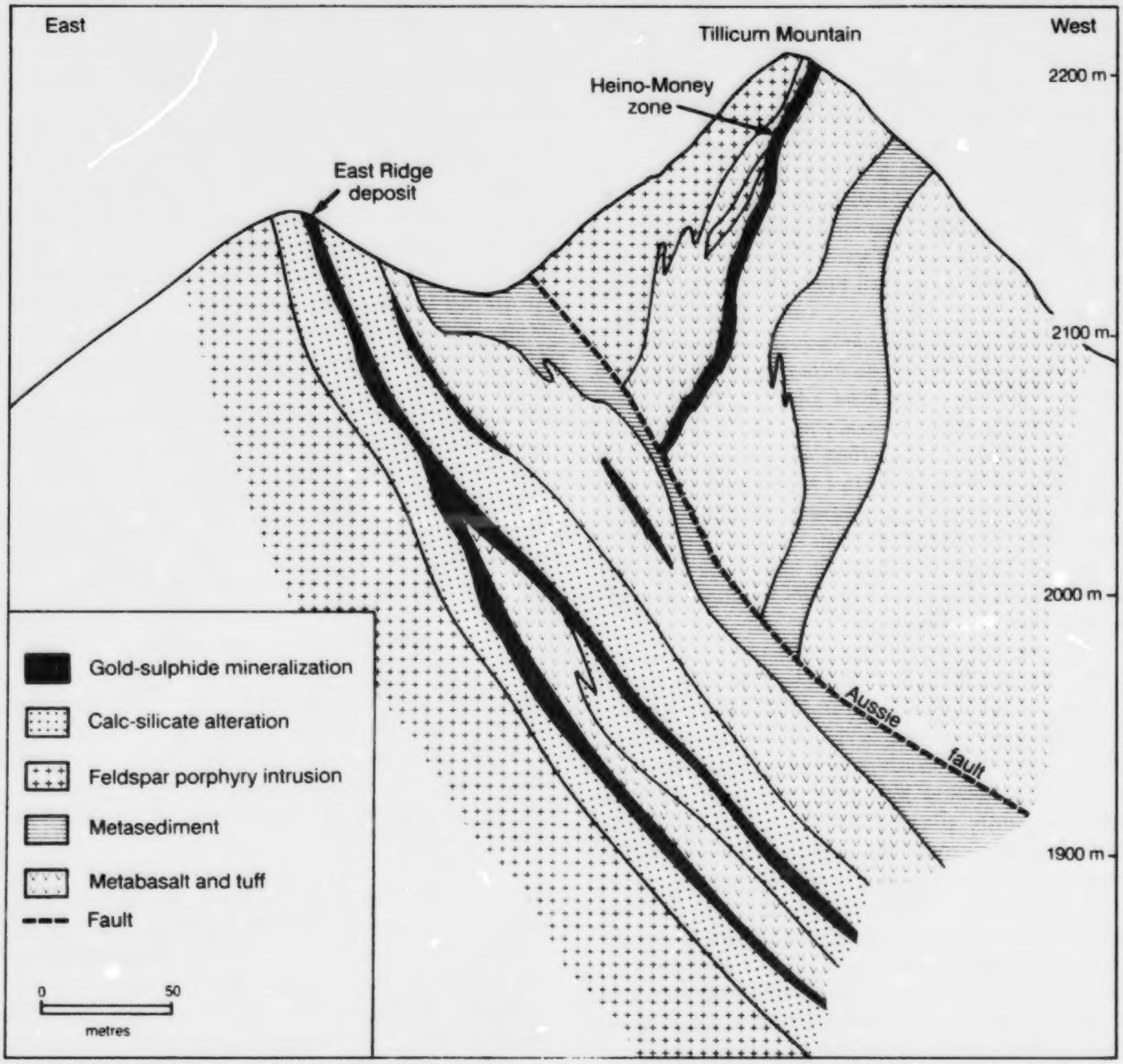

East
Tillicum Mountain
West
2200 m
Heino-Money zone
East Ridge deposit
2100 m
2000 m
1900 m
Aussie fault
Gold-sulphide mineralization
Calc-silicate alteration
Feldspar porphyry intrusion
Metasediment
Metabasalt and tuff
Fault
0
50
metres

Figure 30. Schematic section through the Heino-Money zone and East Ridge deposit, Tillicum Mountain camp. (Modified from unpublished data, courtesy of Cordilleran Engineering Ltd.)

positive correlation with arsenic, silica, calcium and manganese and a negative correlation with alumina, magnesium, sodium, potassium, total iron, strontium and barium, but has no significant correlation with lead and zinc. However, it should be noted that overall, mineralization in both the Heino-Money zone and the East Ridge deposit yield higher gold assays where galena is visible in the skarn, (W.Roberts, personal communication, 1989). The copper values for the entire drill hole (TM82-16) were low (less that 600 ppm). Silver in the silver-rich mineralized zones correlates positively with total iron, potassium, manganese, arsenic, lead and zinc and there is a weak to moderate negative correlation between silver and magnesium, calcium and strontium (Ray *et al.*, 1986a). Neither the Heino-Money zone nor the Silver Queen mine skarns are enriched in mercury, molybdenum, bismuth or cobalt. No samples of the Tillicum Mountain skarns have yet been analysed for tellurium.

Microprobe analyses of mineralized skarn from both the Heino-Money zone and Silver Queen mine reveal that the garnets and pyroxenes in the Tillicum Mountain camp are compositionally distinct from all other PME skarns in the province for which microprobe data are available. Both the pyroxenes and garnets in the Tillicum camp are enriched in manganese. Pyroxenes at the Heino-Money zone contain up to 8 mole per cent johannsenite (Figure 31B) while the iron-poor garnets, which show relatively little compositional zoning, plot midway between grossularite and pyralspite end-members (Figure 31A), ranging in composition from 45 to 55 mole per cent pyralspite. Most of the other well-studied PME skarns in British Columbia (for example, Hedley, Texada Island and Greenwood camps) have iron and/or copper-skarn affinities and occur within oceanic island arc or back-arc basin environments. The reason for the different garnet-pyroxene chemistry in the Tillicum Mountain camp is uncertain. It is possible that the analysed garnets are not related to the skarn mineralization, but formed during the regional metamorphism. However, this seems unlikely, since in the Tillicum Mountain area, garnets are spatially associated with the mineralization, and are generally absent in the surrounding host rocks. Another possible explanation is that since the Tillicum camp is located further east in the province than many other PME-skarns, it may be influenced by continental basement rocks, and represent an unusual, PME-skarn type with lead-zinc skarn affinities.

SILVER QUEEN MINE
(MINFILE 082FNW220)

The Silver Queen mine is located approximately 2.5 kilometres southeast of the Heino-Money zone (Figure 28); it was developed in the 1930s but reportedly work

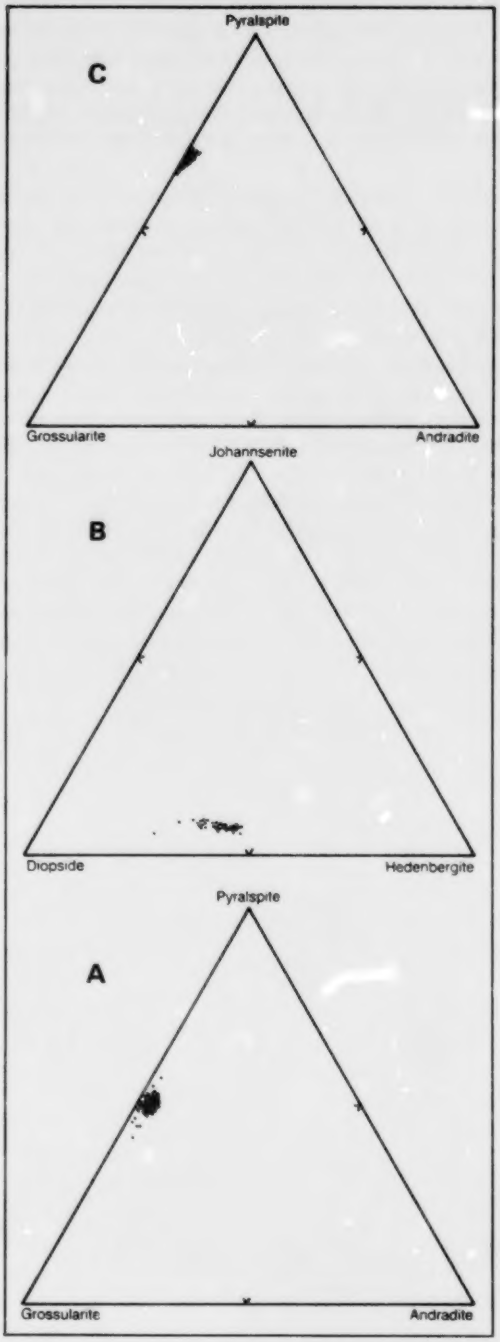


Figure 31. Composition of exoskarn garnets and pyroxenes from the PME skarns, Tillicum Mountain camp. (Analyses by G.E. Ray and G.L. Dawson at The University of British Columbia, Vancouver.)
A = Heino-Money zone (50 garnet analyses).
B = Heino-Money zone (36 pyroxene analyses).
C = Silver Queen mine (32 garnet analyses).

terminated after a spring avalanche killed several miners. Intrusion of feldspar-porphyritic sills into a 30-metre-wide zone of impure calcareous quartzites, siltstones, and thin marble beds was accompanied by stratabound skarn development. These intrusions closely resemble the suite present at Tillicum Mountain, and are locally microcline rich.

Several mineralized layers, each up to 20 metres thick, are present; sulphide mineralization and skarn alteration are found in both the calcareous metasedimentary rocks and the adjacent feldspar porphyry sills. In contrast to the Heino-Money zone, the mineralization is silver rich and no gold is reported.

The skarn assemblage includes quartz, tremolite-actinolite, microcline, clinopyroxene, hornblende, clinozoisite, garnet, biotite and carbonate, with minor amounts of epidote and sphene. Anhedral garnet crystals up to 1 millimetre in diameter have clear margins but abundant inclusions in their cores. Some cores have overgrown and preserve a biotite schistosity that developed during the regional metamorphism. Mineralization extends for 300 metres along strike and grades from 3 to 240 grams silver per tonne. Associated sulphides include pyrite, pyrrhotite, tetrahedrite, sphalerite, galena, pyrargyrite and arsenopyrite.

Whole-rock and trace element analyses on core samples systematically collected from a drill hole (SQ84-10) intersecting the Silver Queen skarn mineralization are given by Ray *et al.* (1986a). The hole cuts a thinly interbedded sequence of calcareous metasedimentary rocks that includes quartzite, siltstone, arkose and marble; some beds are graphitic. All the sedimentary and intrusive rocks in the hole are skarn altered, although skarn development and mineralization are most intense in the exoskarn close to the sill margins. No anomalous gold values are recorded and, like the Heino-Money zone, copper values are generally low, with a maximum value of 271 ppm. There was sporadic enrichment in antimony, but no anomalous bismuth. Silver has a positive correlation with manganese, copper, lead, arsenic and zinc, and a negative correlation with sodium and silica. Enhanced calcium values are recorded at the margins of the silver-rich mineralized zones.

Microprobe analyses of garnets from the Silver Queen mine indicate they are similar in composition to those associated with the auriferous skarn mineralization at the Heino-Money zone; they are iron poor and manganese rich (up to 23 weight per cent MnO), show little compositional crystal zoning, and average 68 mole per cent pyralspite (Figure 31C).

CHAPTER 4

GEOLOGY OF SELECTED PME SKARNS IN THE INSULAR BELT

TEXADA ISLAND CAMP (MINFILE 092F10E106, 107, 112, 258, 259, 269; 092F15E105, 270, 271)

The northern end of Texada Island contains two suites of skarn deposits, namely PME iron skarns and gold and silver-rich copper-bearing skarns. Between 1896 and 1976 approximately 888 kilograms of gold were produced as a byproduct from the iron skarns, and 2425 kilograms of gold were derived from the copper skarns (Table 2).

The gold-enriched copper skarns are concentrated to the north near the town of Vananda (Figure 32), where numerous occurrences of manto-type massive sulphide, sulphide-rich skarn and mineralized shear zones form a continuous, southerly trending belt. Mines in this belt include the Little Billie, Marble Bay, Cornell and Copper Queen, all of which produced copper, gold and silver.

At the southern end of the belt are the PME iron skarns near the town of Gillies Bay (Figure 32). The Lake, Paxton, Prescott and Yellow Kid mines, which were briefly described by Meinert (1984), produced over 20 million tonnes of magnetite ore with byproduct copper, gold and silver.

GENERAL GEOLOGY

Limestone of the Upper Triassic Marble Bay Formation which hosts the skarn mineralization, together with the underlying Texada Formation volcanics, are believed to be correlative with the Quatsino limestone and Karmutsen basalts of Vancouver Island. The Marble Bay Formation comprises bedded, dark grey, fine-grained limestone and coarsely crystalline, white to light grey marble. It outcrops in a continuous, 3-kilometre-long belt which extends from the town of Vananda to the Texada Iron Mines Ltd. property near Gillies Bay further south (Figure 32). Lower greenschist facies amygdaloidal and pillow lavas of the Texada Formation outcrop on either side of the limestone belt. At the Lake iron mine (Figure 32), bedded limestone appears to conformably overlie volcanic rocks which have been replaced by skarn. The bedding in the limestones strikes northwest and dips 30 degrees southwest.

The limestones and volcanics are intruded by small Jurassic stocks and dikes of calc-alkaline composition. The Gillies stock, which is associated with the iron skarns, is the most variable in composition and ranges from

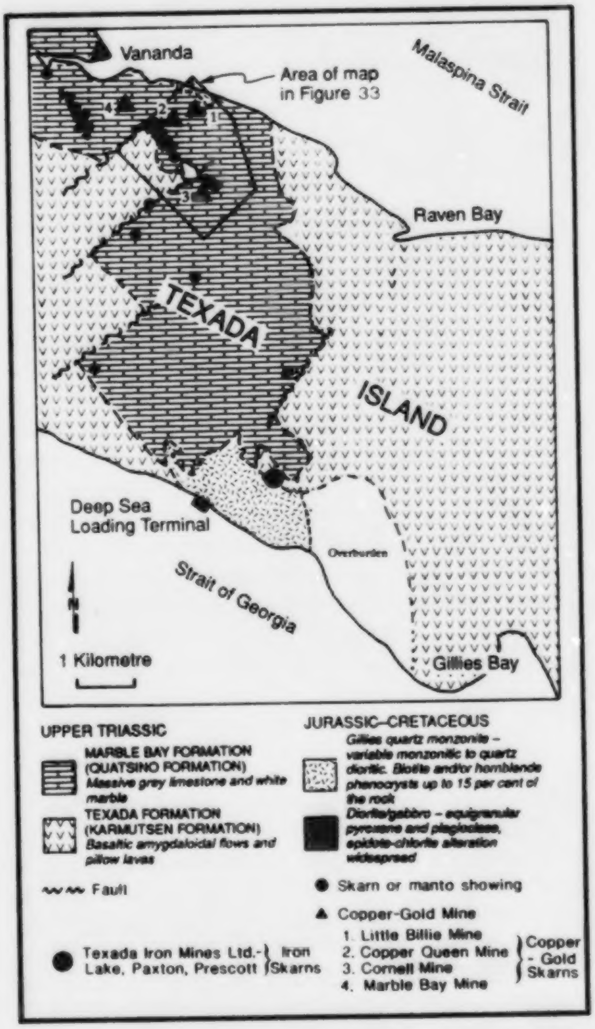
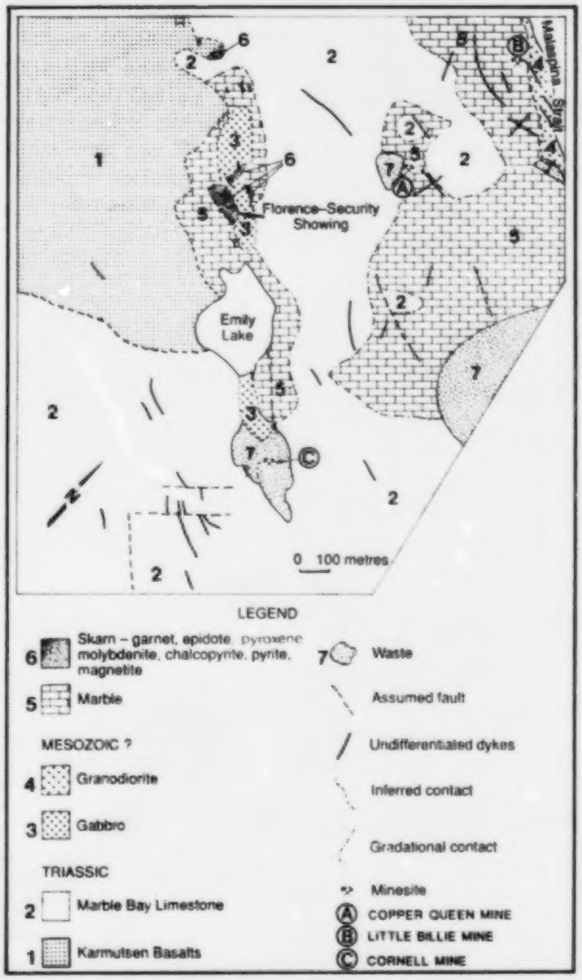

Vananda
Area of map in Figure 33
Malaspina Strait
1
2
3
4
Raven Bay
TEXADA
ISLAND
Deep Sea Loading Terminal
Overburden
Strait of Georgia
N
1 Kilometre
Gillies Bay
UPPER TRIASSIC
MARBLE BAY FORMATION (QUATSINO FORMATION)
Massive grey limestone and white marble
TEXADA FORMATION (KARMUTSEN FORMATION)
Basaltic amygdaloidal flows and pillow lavas
Fault
JURASSIC–CRETACEOUS
Gillies quartz monzonite – variable monzonitic to quartz dioritic. Biotite and/or hornblende phenocrysts up to 15 per cent of the rock
Diorite/gabbro – equigranular pyroxene and plagioclase, epidote-chlorite alteration widespread
Skarn or manto showing
Copper-Gold Mine
1. Little Billie Mine
2. Copper Queen Mine
3. Cornell Mine
4. Marble Bay Mine
Copper - Gold Skarns
Texada Iron Mines Ltd.- Lake, Paxton, Prescott
Iron Skarns

Figure 32. General geology of the Texada Island skarn camp. (Modified after McConnell, 1914.)

granodiorite and quartz monzodiorite to quartz diorite. Recent preliminary U-Pb dating on zircons indicate a Mid-Jurassic age of 176±2 Ma for the Gillies stock (D. Murphy, personal communication, 1989). The Little Billie stock, which is associated with copper-gold skarn mineralization at the Little Billie mine, is tonalitic in composition while the mafic dikes spatially associated with copper skarns at the Cornell mine and the Florence-Security showing are more gabbroic. The Little Billie and Gillies stocks are both light grey, fine to medium-grained equigranular rocks with 5 to 10 per cent biotite and hornblende together with tabular grains of potassium feldspar, quartz and plagioclase. In hand sample, the primary difference between the two intrusions is that the Gillies stock is hornblende rich, while biotite is the dominant ferromagnesian mineral in the stock associated with the Little Billie deposit.



6
2
2
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3
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Florence-Security Showing
5
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A
2
Malaspina Strait
B
5
Emily Lake
2
5
3
7
C
2
2
7
2
0 100 metres
LEGEND
6 Skarn – garnet, epidote, pyroxene molybdenite, chalcopyrite, pyrite, magnetite
5 Marble
MESOZOIC ?
4 Granodiorite
3 Gabbro
TRIASSIC
2 Marble Bay Limestone
1 Karmutsen Basalts
7 Waste
Assumed fault
Undifferentiated dykes
Inferred contact
Gradational contact
Minesite
A COPPER QUEEN MINE
B LITTLE BILLIE MINE
C CORNELL MINE

Figure 33. General geology of the Little Billie - Copper Queen mines area, Texada Island. (For location *see* Figure 32; geology by A.D. Ettlinger, courtesy of Vananda Gold Ltd.)

The gabbros in the central part of the belt generally form small bodies which are exposed at the Cornell mine, south of Emily Lake, and in the Florence-Security area, north of the lake (Figure 33). It is uncertain whether these gabbros are related to the skarn mineralization at the Cornell mine and Florence-Security area. However, there are clear distinctions between the skarns in these two areas and those at the Little Billie mine. The gabbro is a dark grey, medium to coarse-grained rock that contains uralitized and chloritized pyroxene phenocrysts in a matrix of plagioclase microlites partially altered to sericite and clay. Secondary magnetite, pyrite and chalcopyrite are disseminated throughout the rock.

SKARN MINERALIZATION

The average ore grade of the copper-skarn mineralization on Texada Island is approximately 3 per cent copper and 8 grams gold per tonne. At the Little Billie mine, gold-silver-copper mineralization occurs in irregular, pipe-like bodies along a granodiorite-marble contact. These ore shoots plunge 45 degrees south and are open to depth. Stevenson (1945) described three skarn types in the mine workings: endoskarn consisting of light tan grossularitic garnet with clinopyroxene, wollastonite and clusters of quartz, epidote and feldspar; light olive-green andradite associated with wollastonite and clinopyroxene; and coarsely granular, dark brown andradite containing considerable magnetite. The endoskarn is described as barren, while the latter two skarn types contain chalcopyrite and bornite, and generally constitute the ore.

A 1984 diamond-drill hole at the Little Billie mine intersected skarn along the granodiorite-marble contact; this skarn contains coarse-grained banded wollastonite with light to dark green euhedral crystals of concentrically zoned garnet up to 3 centimetres wide. Finer grained, subhedral brown garnet, associated with dull green clinopyroxene, crosscuts the wollastonite-garnet skarn. There is a progressive increase in dark green fine-grained clinopyroxene in both skarn types outwards from the intrusive contact.

In thin section the barren skarn is seen to contain fine-grained intergrowths of tremolite and quartz which replace zoned colourless to brown, anhedral isotropic garnet; sulphides are generally absent. A mineralized skarn sample from the same drill hole, which assayed 7.9 grams gold and 29.8 grams silver per tonne over 2.65 metres, contains bands of bladed wollastonite with minor brown garnet, clinopyroxene and quartz. Reflected light microscopy shows blebs of gold 20 to 50 microns across attached to grains of bornite. The bornite, and lesser chalcopyrite, grow between blades of wollastonite which sometimes results in an accicular habit to the sulphides. Molybdenite is abundant locally, occurring within the endoskarn and in coarse, brown, garnet-chalcopyrite skarn. Magnetite, sphalerite, galena, scheelite, hessite, gold and silver are also observed in minor amounts.

The Cornell mine and Florence-Security showing (Figure 33) are located in areas of garnet and epidote-rich skarn containing patches of fine-grained clinopyroxene hornfels. Gold mineralization occurs in chalcopyrite-rich zones which appear to be associated with epidote and amphibole replacement of garnet and pyroxene, respectively. While molybdenite is abundant locally, as at the Little Billie mine, the sulphide mineral assemblage is distinct with pyrrhotite, chalcopyrite and pyrite being most common, while minor chalcocite is also reported by Lakes (1930).

The magnetite-rich skarns present on the Texada Iron Mines property near Gillies Bay (Figure 32; Appendix 1) are associated with the Gillies quartz monzonite. This intrusion is texturally similar to the granodiorite at the Little Billie copper mine, but there are significant variations between these two areas of skarn mineralization. In the magnetite-rich mineralization, skarn is equally well developed within volcanics, limestone and quartz monzonite but at the Little Billie mine, massive marble with minor silty interbeds is the only economically important host for copper mineralization. The mineralogy of the iron skarns is dominated by dark brown garnet and epidote, with lesser amounts of iron-rich pyroxene, actinolite, plagioclase and scapolite. Pyrrhotite is the main sulphide, with minor pyrite and chalcopyrite which may reflect lower $f(O)_2$ conditions during iron skarn formation, contrasting with the copper-gold skarns which contain bornite, abundant pyrite and chalcopyrite as the primary sulphides.

Electron microprobe analyses of garnet and pyroxene from the Texada Island skarns are presented in Figures 23A and 25A, respectively. Garnet compositions within the copper-gold skarns are quite variable; end-member andraditic garnets occur as isotropic subhedral grains at the Little Billie mine, and as isotropic, pale green cores rimmed by isotropic, clear garnet, intermediate in composition between grossularite and andradite (grandite), in the Florence-Security area. Anisotropic garnets are observed only in the Florence-Security area; they are concentrically zoned, although variations in total iron across these zones are generally less than 4 weight per cent Fe_2O_3. The compositions of near end-member andradite at the Little Billie mine are believed to represent the brown andradite garnets described by Stevenson (1945) which crosscut the earlier wollastonite-garnet skarn. The isotropic garnets, partially replaced by tremolite and quartz as described above, are intermediate in composition, ranging from Ad 54 to Ad 66 mole per cent.

At the Lake iron mine, the brown isotropic garnet has a composition ranging from Ad 38 to Ad 65 mole per cent (Figure 23A). Anisotropic garnet is only observed at the Paxton iron mine, where it occurs as clear overgrowths on honey-brown isotropic cores. This suggests andradite was replaced and/or overgrown by later aluminous garnet from a fluid that became progressively depleted in iron.

Pyroxene at the Little Billie mine and Florence-Security showing ranges in composition from end-member diopside to Hd 58 with less than 5 mole per cent johannsenite and up to 2.2 weight per cent Al_2O_3. The pyroxenes in the PME iron skarns are slightly more iron rich than those associated with the copper-gold skarns, varying from Hd 27 to Hd 46, and containing less than 2.5 mole per cent johannsenite and up to 2.9 weight per cent Al_2O_3 (Figure 25A).

ZEBALLOS CAMP (MINFILE 092E15W002; 092L2W068, 127)

Several areas of PME skarn and quartz-gold vein mineralization occur near the village of Zeballos on the northwest coast of Vancouver Island (Figure 34). Limited placer mining activity began along the Zeballos River in 1907 and lode gold mineralization was discovered in the area in 1924 (Stevenson, 1950). Zeballos Iron Mines Ltd. produced magnetite from the gold-poor iron skarns on the FL property in the early 1960s. Gold-enriched skarn mineralization occurs some distance from the FL property at the Hiller and Beano showings (Figure 34); these two properties were visited in the course of this study. Current exploration activity is focused on the Hiller showing which is an area of auriferous amphibole-rich skarn mineralization.

HOSTROCK LITHOLOGY AND SKARN MINERALIZATION

The skarns in the Zeballos district are separable into iron skarns and gold skarns. The iron skarn mineralization (FL deposit) is confined to the thick massive crystalline limestone of the Quatsino Formation, but the amphibole-rich gold-skarn mineralization at the Hiller and Beano properties is hosted by the volcaniclastic and argillite-rich members of the Parson Bay and Bonanza formations (Figure 34).

At the Hiller showing (Artlish, MINFILE 092L068, 127), skarn outcrops along Toray Creek approximately 15 kilometres northwest of Zeballos. The skarn zone lies

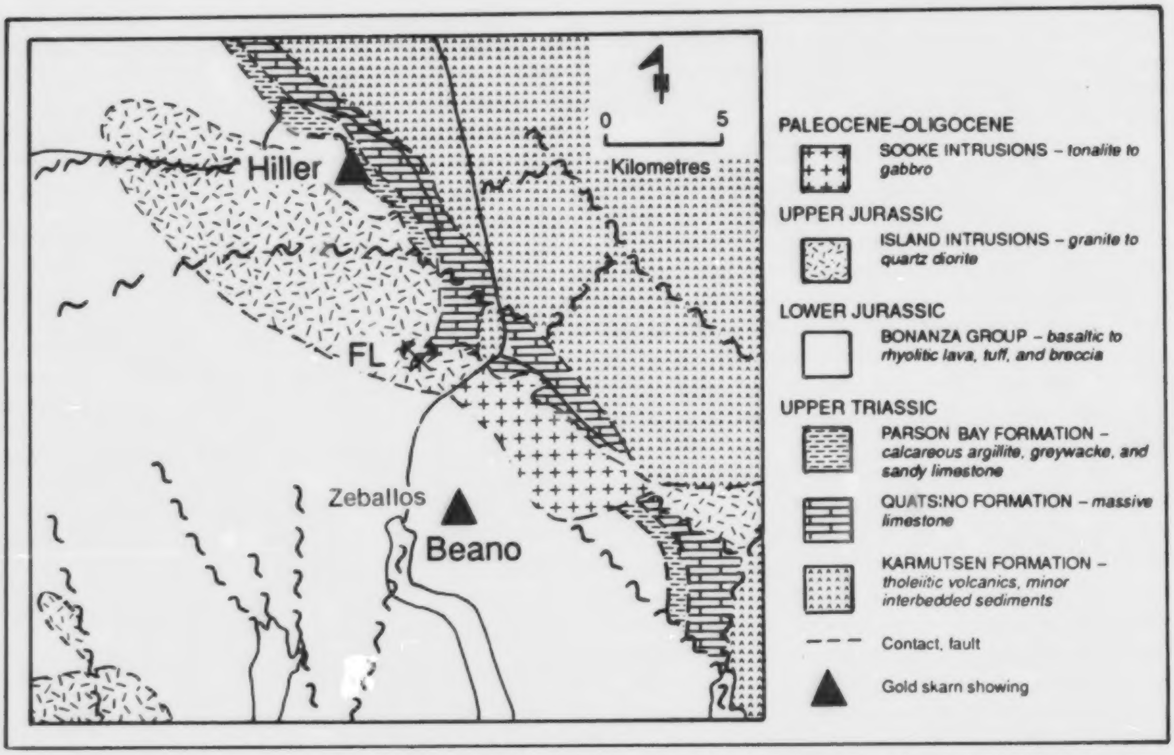
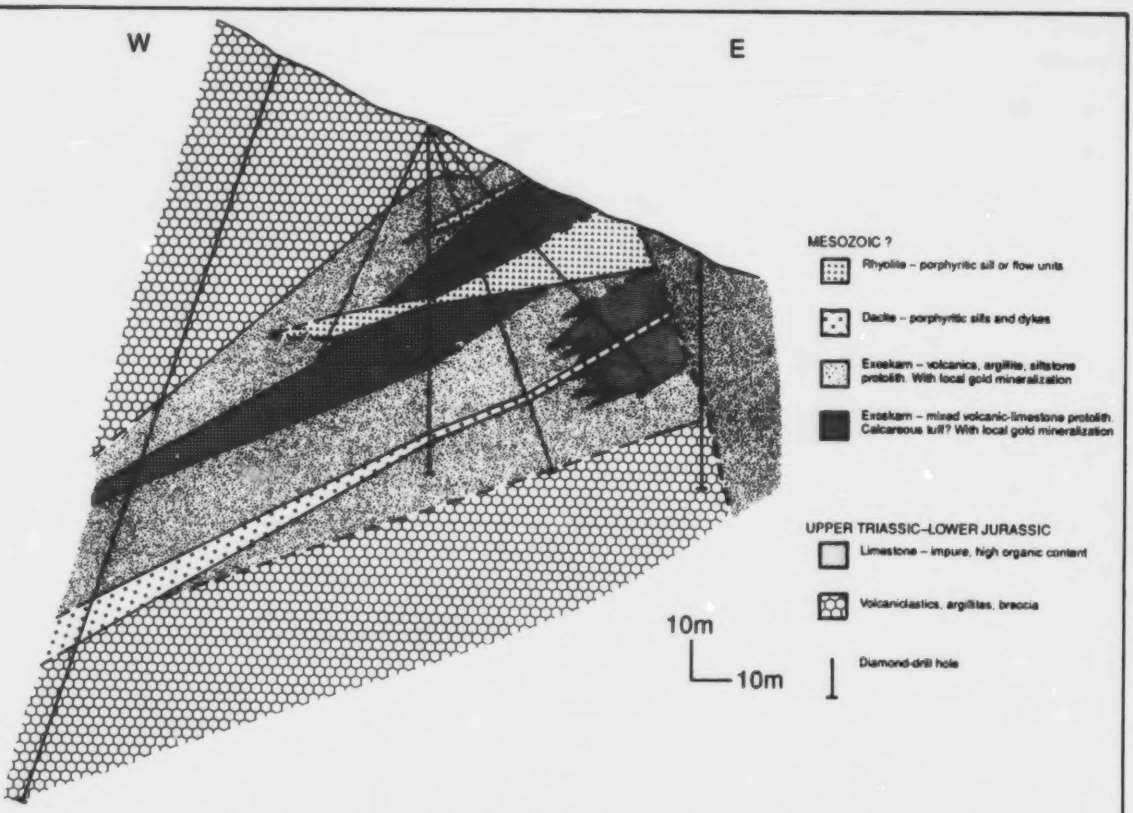

Hiller
FL
Zeballos
Beano
0
5
Kilometres
PALEOCENE–OLIGOCENE
SOOKE INTRUSIONS – tonalite to gabbro
UPPER JURASSIC
ISLAND INTRUSIONS – granite to quartz diorite
LOWER JURASSIC
BONANZA GROUP – basaltic to rhyolitic lava, tuff, and breccia
UPPER TRIASSIC
PARSON BAY FORMATION – calcareous argillite, greywacke, and sandy limestone
QUATSINO FORMATION – massive limestone
KARMUTSEN FORMATION – tholeiitic volcanics, minor interbedded sediments
Contact, fault
Gold skarn showing

Figure 34. General geology of the Zeballos camp, Vancouver Island, and location of the skarn deposits. (Modified after Hoadley, 1953, and Falconbridge Limited, unpublished reports.)

within rocks originally assigned to the lower section of the Bonanza Formation by Hoadley (1954) and subsequently described as Parson Bay Formation by Muller (1977). Lithologies include intercalated sequences of aquagene tuffs, turbiditic argillites, impure limestones and volcanic breccias. These dip 20 to 30 degrees toward the Zeballos batholith, which outcrops approximately 2.5 kilometres to the west. The only intrusive rocks identified at the Hiller showing are unaltered, medium-grained andesite and rhyolite porphyries which are commonly seen in drill core. These porphyries, which form semiconcordant sills and small crosscutting plugs, are apparently unrelated to the skarn alteration. It is possible that the amphibole-rich Hiller skarn is related to the Zeballos batholith which was originally dated at 148±8 Ma by K:Ar methods using phlogopite associated with the FL iron skarn (Carson *et al.*, 1971). However, recent preliminary K:Ar analysis of hornblende suggests an age of c. 185 Ma for the batholith, (D. Murphy, personal communication, 1989). Whole-rock chemical data and calculated CIPW normative mineralogy from several phases of this pluton suggest that this batholith has granitic, quartz monzodioritic and quartz dioritic components.

Skarn is complexly interfingered with unaltered host-rock at the Hiller property, which reflects extensive fracturing and faulting of the lithologically variable protolith. A simplified geological cross-section of the showing is presented in Figure 35. No consistent calc-silicate zoning has been recognized in the skarn. Alteration forms a 60 to 90-metre-thick zone which is sandwiched between unaltered calcareous volcaniclastics, argillite and siltstone. At least two different types of skarn are present. Amphibole is by far the most abundant mineral observed and in one skarn type it commonly occurs in clusters of dark green, 1 to 3-millimetre-long euhedral crystals. Light green euhedral crystals of pyroxene, together with calcite, quartz, chlorite, pyrrhotite, magnetite, pyrite and chalcopyrite, are also present in minor amounts. In thin section, the amphibole appears zoned with strongly pleochroic light to dark green cores and clear to pale green rims. This type of skarn preferentially replaces a volcanic-rich protolith.

A second skarn type, which is volumetrically less important than the amphibole skarn, contains abundant pyroxene, carbonate and sulphides, with lesser amphibole. It is commonly brecciated and contains rare pods of unreplaced marble together with blocks of amphibole-rich skarn. This possibly represents a sedimentary gravity slide that formed when volcanic fragments were moved down a paleoslope and deposited into a carbonate ooze.



W
E
MESOZOIC ?
Rhyolite – porphyritic sill or flow units
Dacite – porphyritic sills and dykes
Exoskarn – volcanics, argillite, siltstone protolith. With local gold mineralization
Exoskarn – mixed volcanic-limestone protolith. Calcareous tuff? With local gold mineralization
UPPER TRIASSIC–LOWER JURASSIC
Limestone – impure, high organic content
Volcaniclastics, argillites, breccia
Diamond-drill hole
10m
10m

Figure 35. Geological cross-section through the Hiller (Artlish) PME skarn. (Compiled from drill-hole data logged by A.D.Ettlinger.)

Diamond drilling suggests that the gold mineralization favours this mixed-protolith skarn (Ettlinger and Ray, 1988).

Pyroxene from skarn that replaces limestone is hedenbergitic in composition, ranging from Hd 76 to Hd 94 mole per cent, and contains up to 4 mole per cent johannsenite (Figure 25B). The amphiboles are distinctly compositionally zoned. The deep green cores are chlorine-rich ferroedenitic to hastingsitic hornblende, while the paler ferro-actinolitic rims are less variable in composition (Figure 36).

The notable absence of garnet and significant amphibole and pyroxene at the Hiller showing support the hypothesis that this deposit represents skarn formed distal to the Zeballos batholith.

Amphibole-rich skarn, similar to that on the Hiller property, outcrops on the Beano claims, approximately 3 kilometres east of Zeballos (Figure 34). The main Beano showing lies within Bingo Creek canyon, at an elevation of about 760 metres. It is described by Muller *et al.* (1981) as a pyrrhotite-rich actinolitic skarn hosted by Bonanza volcanics. Mineralization consisting of fibrous actinolite, fine-grained clinopyroxene, pyrrhotite and lesser chalcopyrite replaces a limestone unit that is intruded by diorite. Quartz-carbonate veins containing auriferous pyrrhotite are also reported.

The showings along the west rim of the canyon, at the head of an old aerial tramway, were visited during this study; the workings consist of an adit and a stripped area on a heavily rusted outcrop of massive, fine to coarse-grained amphibole skarn which contains clinopyroxene, calcite, chlorite, quartz, pyrrhotite, arsenopyrite and pyrite. The limestone is totally replaced by skarn, and dark greenish grey, fine-grained volcanic rock is the only other rock type observed. The volcanics are hornfelsed, have undergone minor silicification, and are cut by dark green amphibole veins with white albitic(?) envelopes.

Electron microprobe analyses of pyroxene from amphibole-pyrrhotite skarn are shown in Figure 25B. The pyroxene, which is ferrosalitic, averages about Hd 66 mole per cent and is slightly less iron rich than pyroxene at the Hiller deposit. Analyses indicate that the amphiboles in skarn at the Beano showing are also chlorine rich and similar to those on the Hiller claims.

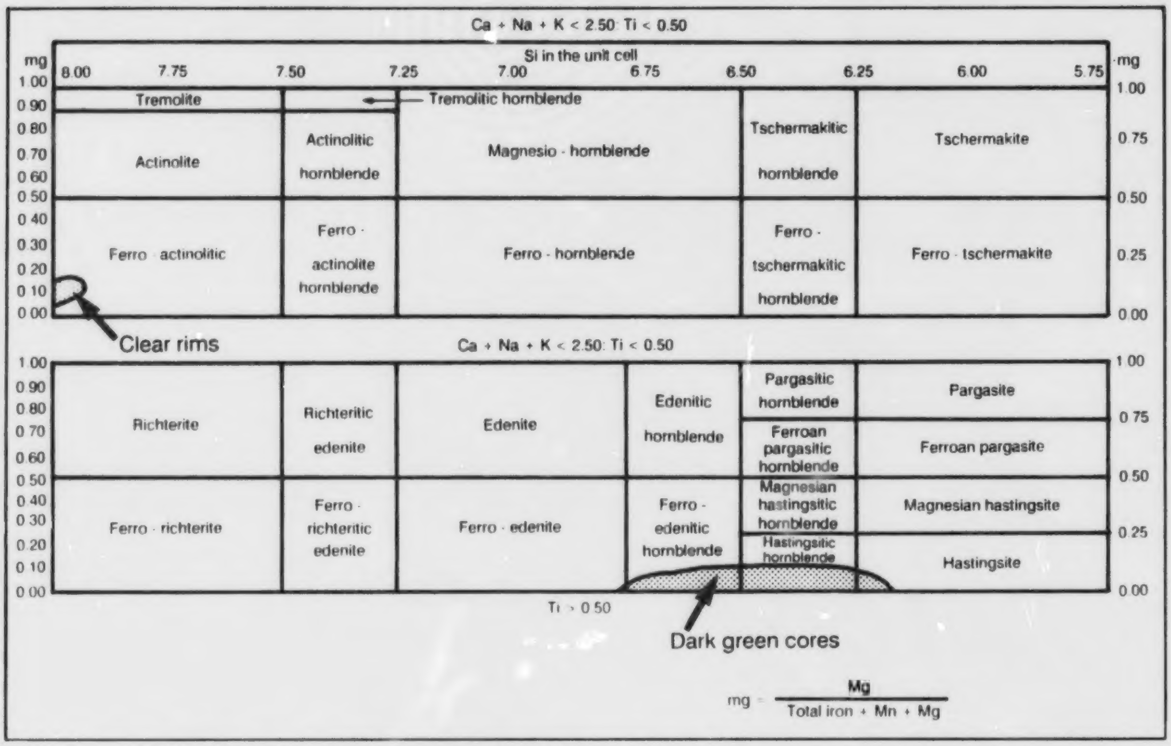


Figure 36. Composition of amphiboles from the Hiller PME skarn, Zeballos. Note contrasting compositions for the margins and cores. (Amphibole classification from Leake, 1978.)

MERRY WIDOW, KINGFISHER, OLD SPORT MINES (MINFILE 092L035, 044, 045, 046)

Iron and copper with byproduct gold and silver were produced from several skarn deposits approximately 30 kilometres southwest of Port McNeill, near the south shore of Benson Lake. During the period from 1962 to 1973 the Old Sport mine produced 3869 kilograms of gold, 117 31 kilograms of silver and 411 93 tonnes of copper from 2.6 million tonnes of ore. From 1957 to 1967, 3.4 million tonnes of iron ore were mined from the Merry Widow, Kingfisher and Ravel open pits which are located approximately 3 kilometres south of the Old Sport mine. These deposits, together with a number of smaller occurrences, form a suite of PME iron and copper skarns that are spatially associated with the Middle Jurassic Coast Copper stock.

HOSTROCK LITHOLOGY AND MINERALIZATION

The orebodies lie at the contact between the Coast Copper stock and the Upper Triassic to Lower Jurassic Karmutsen, Quatsino and Bonanza formations. The eastern two-thirds of this oval-shaped stock is dioritic to gabbroic in composition while the remainder is monzonitic (Sangster, 1969). Phlogopite related to the skarn alteration has been dated at 181±8 Ma which suggests the Coast Copper stock is one of the oldest intrusions on Vancouver Island (Carson, 1973).

Skarn mineralization at the Merry Widow and adjacent Kingfisher and Raven iron mines is typical of other magnetite-rich skarns along the west coast of British Columbia and southeastern Alaska (Sangster, 1969; Meinert, 1984; Myers, 1985). A coarse-grained gabbroic phase of the pluton, containing abundant uralitized pyroxene, plagioclase, ilmenite, magnetite and apatite, intrudes Bonanza volcaniclastics, greenstone and underlying Quatsino limestone (Figure 37). Except for the smaller Kingfisher pit which contains only marble, skarn occurs primarily in the volcaniclastic rocks. Lapilli and crystal tuffs and lesser greenstone are replaced by garnet-epidote-clinopyroxene-amphibole skarn in the Merry Widow mine. Several discontinuous breccia zones comprising magnetite-calcite fragments rimmed by coarse, brown garnet, occur in the exoskarn, between the intrusive contact and marble. This skarn, which appears to

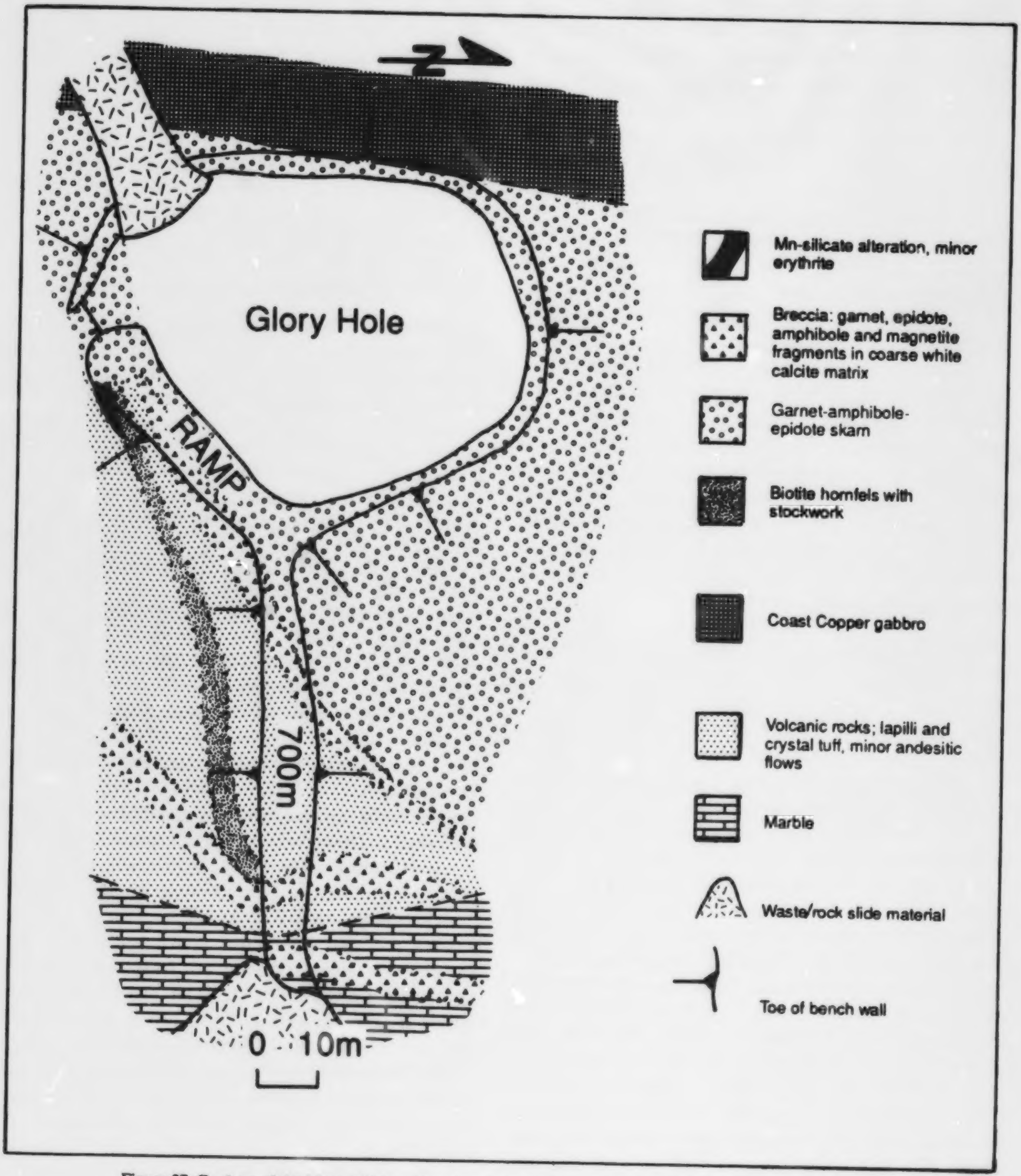

N
Glory Hole
RAMP
700m
0 10m
Mn-silicate alteration, minor erythrite
Breccia: garnet, epidote, amphibole and magnetite fragments in coarse white calcite matrix
Garnet-amphibole-epidote skarn
Biotite hornfels with stockwork
Coast Copper gabbro
Volcanic rocks; lapilli and crystal tuff, minor andesitic flows
Marble
Waste/rock slide material
Toe of bench wall

Figure 37. Geology of the Merry Widow mine glory hole, 700-metre level. (Geology by A.D. Ettlinger.)

crosscut the stratigraphy, is also characterized by repetitive bands of massive magnetite interlayered with zones rich in epidote, amphibole, calcite or garnet.

The fine-grained volcanic rocks are recrystallized to a pyroxene hornfels which is locally overprinted by zoned garnet-calcite±pyroxene veins. Garnets typically have isotropic cores of end-member andradite grading outward to anisotropic grossularitic rims (Figure 23E). The pyroxenes replacing volcanic rock have compositions intermediate between diopside and hedenbergite (Hd 40 to Hd 63 mole per cent; Figure 25D). Except for the isotropic andradite cores which characterize the garnets replacing the volcanic rocks, it is difficult to distinguish differences in either garnet or pyroxene compositions among the other protolith types (gabbro, volcanics and marble; Figures 23E and 25D).

Sulphide mineralization is best developed either within limestone, or along volcanic-limestone contacts. The sulphides include chalcopyrite, pyrite, sphalerite and arsenopyrite and postdate the main silicate skarn alteration. Electron microprobe analyses show that pyrite from coarse-grained garnet-amphibole skarn at the Merry Widow pit contains up to 1.15 per cent arsenic, 2.65 per cent cobalt and anomalous gold. Cobalt enrichment is also observed as fine-grained erythrite in a zone of pink potassium feldspar replacement of greenstone.

A sample of chalcopyrite-rich magnetite skarn from a bench wall in the Merry Widow pit assayed 4.5 ppm gold, 64 ppm silver and 610 ppm cobalt, while another sample from the gossan above this zone contained 32 ppm gold, 200 ppm silver and 1600 ppm cobalt. Grab sampling of sulphide-rich ore from the main orebody returned an average of 19.2 grams gold per tonne from seven samples (Eastwood and Merrett, 1962).

The Old Sport mine workings are no longer accessible; however Jeffrey (1960) and McKechnie and Merrett (1967) describe the geology of the mine area. The skarn ore zone is located near the contact between the Coast Copper stock and basic volcanic rocks, marbles and a series of intrusive sills. While the Quatsino limestone is present in the mine workings, the primary marble host is probably an interflow limestone unit near the top of the Karmutsen Formation. Samples collected from the mine dump during this study indicate the skarn is chalcopyrite and pyrrhotite rich. One massive chalcopyrite sample with 15 to 20 per cent magnetite and minor dark brown garnet returned 6.5 grams gold and 42 grams silver per tonne, with 19.3 per cent copper, 0.07 per cent zinc and 250 ppm cobalt. Skarn consists of green amphibole, considerable epidote, lesser dark green-black garnet, minor pyroxene, calcite and fibrous magnetite after hematite.

NANAIMO LAKES (MINFILE 092F182)

Gold-copper mineralization hosted by skarn and an overlying stratiform hematitic horizon outcrops 4 kilometres west of the north end of Fourth Lake, approximately 40 kilometres west of Nanaimo. The skarn lies on the Jane, Toni, Kathy and Larry (JTKL) claims while the auriferous hematite zone is located on the adjacent Villalta property. The age of the Villalta mineralization and its relationship to the underlying skarn is uncertain.

HOSTROCK LITHOLOGY

Paleozoic Sicker Group volcanic and sedimentary rocks underlie most of the area which is within the northwest half of the Cowichan - Horne Lake uplift (Muller, 1980). The Myra and overlying Buttle Lake formations, which form the upper two-thirds of the Sicker Group, outcrop on both claim blocks and host the skarn mineralization on the JTKL property. These two units have recently been renamed the Cameron River and Mount Mark formations, respectively (Sutherland Brown *et al.*, 1986). The Cameron River Formation comprises medium to dark green siliceous tuff and black argillite which are locally altered to a brown biotite or pale green pyroxene hornfels. The Mount Mark Formation in the claim area comprises massive white marble which represents a recrystallized crinoidal limestone with minor siltstone and chert interbeds.

The stratigraphic relationships above the Mount Mark Formation are less clear. On the Villalta claims, the Mount Mark limestone is unconformably overlain by a heterolithic breccia. This volcanic-rich breccia hosts the gold-hematite mineralization and has been variously described as Cretaceous Nanaimo Group conglomerate (Chandler and Runkle, 1985), or Paleozoic volcanic agglomerate (S. Quin, personal communication, 1987). The breccia contains angular clasts of fine-grained dark green volcanic rock and lesser amounts of subrounded granitic and cherty fragments; the volcanic fragments are similar to lithologies observed on the JTKL claims. The breccia matrix is generally dark green to brown and comprises fine to medium-grained fragments of probable volcanic origin. The predominant volcanic component, and lack of marine or fluvial features commonly seen in Nanaimo Group sediments, suggest the breccia belongs to the Sicker Group.

The plutonic rocks in this area include Early to Middle Jurassic Island intrusions of granitic to dioritic composition, and skarns are developed where these intrusions cut limestone-volcanic contacts. On the JTKL claims, outcrops of a small stock are altered to endoskarn which suggests a genetic link between the intrusion and skarn formation. Major oxide whole-rock analyses of this stock show it to vary from granite to quartz monzodiorite in composition (Figure 39C). Recent preliminary U-Pb dating on zircons suggest an age of approximately 177 Ma (D. Murphy, personal communication, 1989) which is similar in age to the skarn-related Gillies stock on Texada Island.

A younger phase of plutonism is represented by the Tertiary Catface intrusions that are sparsely represented by hornblende feldspar porphyry sills and dikes which form small outcrops and short drill-hole intersections. These intrusions are not spatially associated with any known skarn mineralization in the claim area.

SKARN MINERALIZATION

Skarn mineralization on the JTKL claims is garnet rich and occurs both in volcaniclastic and argillaceous rocks of the Cameron River Formation and in crinoidal limestone of the overlying Mount Mark Formation. Epidote-amphibole endoskarn is common on the surface and occurs adjacent to massive garnet skarn which replaces limestone on surface and at depth. The latter consists primarily of coarse-grained euhedral garnet varying in colour from bright yellow to dark brown. Minor amounts of wollastonite, calcite, dark green fine-grained pyroxene, fine-grained bladed tremolite, prehnite, quartz, chlorite, sphene and potassium feldspar also occur in the skarn. In thin section, garnet is seen to form isotropic clots that poikalitically enclose numerous small pyroxene crystals. Electron microprobe analyses indicate this garnet is variable in composition, ranging from Ad 9 to Ad 66 mole per cent (Figure 23H); however, no compositional variation was identified amoung different coloured garnet varieties. The small pyroxene crystals enclosed in the garnet vary from Hd 6 to Hd 29 mole per cent (Figure 25G); they contain less than 1.5 mole per cent johannsenite component and up to 3.4 weight per cent Al_2O_3.

Where skarn replaces volcaniclastic rocks or argillite, the garnet:pyroxene ratio decreases and the amount of dark green chlorite increases relative to skarn hosted by limestone. In this protolith epidote, calcite and quartz replace the earlier garnet, and wollastonite and tremolite are generally absent. Garnets are more iron rich than those developed in a limestone protolith, and they contain isotropic cores of pure andradite and anisotropic rims down to Ad 42 (Figure 23H). The composition of pyroxenes developed in the volcaniclastic and argillite protoliths shows little difference from those developed in the limestone (Hd 5 to Hd 12, mole per cent johannsenite and up to 1.5 weight per cent Al_2O_3; Figure 25G).

Veinlets of earthy hematite crosscut both skarn types and bright red hematite completely replaces the zoned garnet. Coarse specular hematite and fibrous magnetite after hematite occur in minor amounts. The sulphide content is generally low with pyrite forming fine-grained clots and irregular disseminations throughout the skarn and scattered through the underlying volcaniclastic rocks. Chalcopyrite is present in trace amounts, generally associated with disseminated magnetite, and arsenopyrite was noted in one drill-hole intercept. Surface and diamond-drill grab samples of skarn returned assays up to 370 grams per tonne gold, 54 ppm silver, 2.6 per cent copper, 177 ppm cobalt and 120 ppm arsenic. Although gold and silver assays in rock samples are low overall, the large amount of skarn alteration observed in volcaniclastic rocks, argillite and limestone, together with the enrichment in copper, cobalt and arsenic, are characteristics favourable for PME skarn formation.

CHAPTER 5

GEOLOGY OF SELECTED PME SKARNS IN THE COAST BELT

BANKS ISLAND (MINFILE 103G024, 025, 031, 033, 035)

Banks Island, located in Hecate Strait due east of the Queen Charlotte Islands (Figure 38), contains a number of quartz-pyrite and massive sulphide veins and mineralized shear zones hosted by skarn-altered and metamorphic rocks. Skarn mineralization was first recognized in 1960 at the Discovery showing, and additional mineralization was identified in the Bob zone in 1964. Surface trenching by Trader Resources Corporation during 1987 exposed a massive sulphide vein which cuts marble and metapelites at the Tel zone. Drill-indicated probable reserves in the Tel zone are reported by Trader Resources as 95500 tonnes averaging 16.21 grams gold per tonne while reserves at the Discovery deposit are reported as 38200 tonnes averaging 17.1 grams gold per tonne.

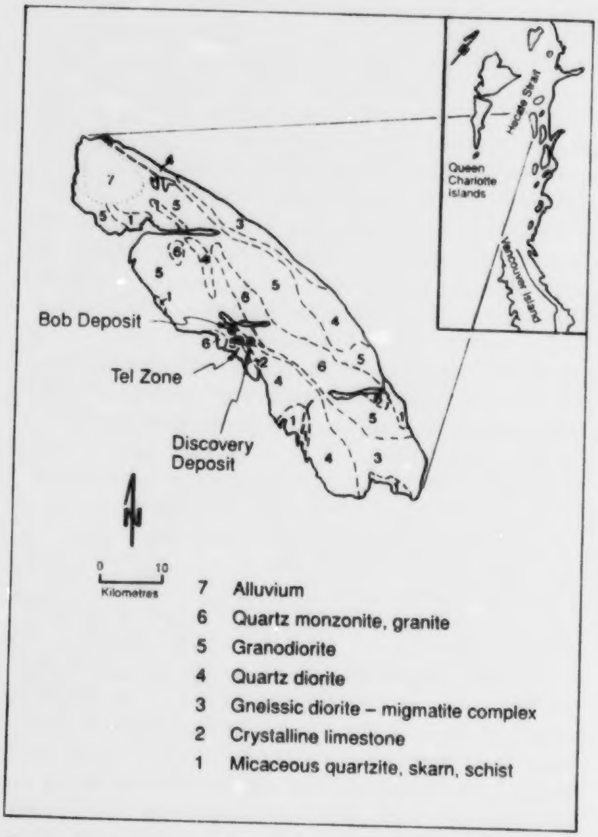


Figure 38. General geology and deposit locations, Banks Island. (Modified from Trader Resources Corporation, unpublished company reports.)

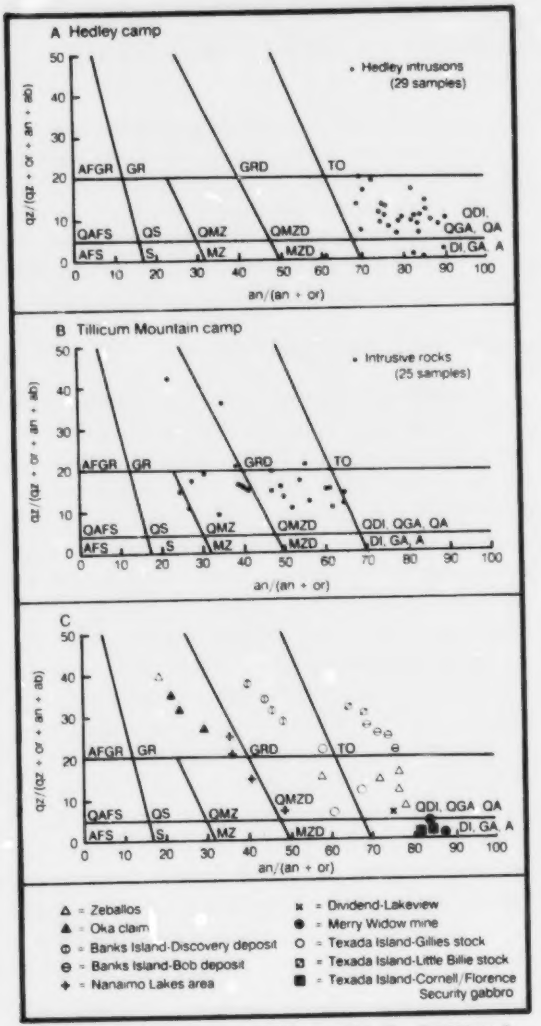
HOSTROCK LITHOLOGY

Banks Island is mainly underlain by intrusive rocks of the Coast plutonic complex and less extensive metasedimentary rocks (Figure 38). The intrusive rocks are compositionally zoned from a monzonitic to granodioritic core surrounded by a quartz dioritic phase which in turn grades outward to a gneissic dioritic-gabbroic migmatite margin. Whole-rock geochemical analyses and normative mineralogy plots of the intrusions present at the Discovery and Bob deposits show them to be granodioritic and tonolitic in composition, respectively (Figure 39C). Late alaskitic dikes crosscut both the intrusions and the country rocks. Surface mapping and detailed petrographic work by Trader Resources suggest that the intrusive rocks are related and form part of a single zoned pluton (Shearer *et al.*, 1987). The Paleozoic(?) metasedimentary rocks form long lenticular northwest-striking units comprising coarse-grained, banded, light grey to green marble, gneiss and migmatite. These sediments host the skarn mineralization at the Discovery deposit and, to a lesser extent, at the Bob deposit.

STRUCTURE AND SKARN MINERALIZATION

Banks Island is bounded by subvertical northwest-striking right-lateral faults. Subparallel to these are secondary near-vertical faults that place metasedimentary rocks in contact with the intrusions. These structures are cut by westerly trending lineaments defining subsidiary shears and tension fractures. The intersections of these later discordant lineaments and the near-vertical secondary faults were the exploration targets for early prospectors.

Skarn at the Discovery deposit is localized along a northwest-striking fracture zone which separates biotite granodiorite from marble. Endoskarn consists of subequal amounts of dark green, fine to medium-grained amphibole and dark green euhedral zoisite with minor amounts of garnet and pyroxene. This grades into exoskarn which replaces marble. The exoskarn contains dark brown medium-grained garnet as the primary calc-silicate phase with lesser amounts of pyroxene. Remnant patches of marble are observed within the skarn zones. The garnet-pyroxene skarn has commonly undergone retrograde alteration; the pyroxene is replaced by amphibole and calcite, whereas garnet is altered to chlorite, epidote, calcite and rutilated quartz. The garnet is grossularitic in composition, mostly containing less than 4 mole per cent pyralspite, although one sample contains 12 mole per cent pyralspite component (Figure 23F). Pyroxene from the same skarn is zoned with diopside cores and rims richer in hedenbergite (Figure 25E).



qz = quartz, or = orthoclase, an = anorthite, ab = albite, AF = alkali feldspar, S = syenite, MZ = monzonite, MZD = monzodiorite, DI = diorite, GA = gabbro, A = anorthosite, GR = granite, GRD = granodiorite, TO = tonalite, Q = quartz

Figure 39. Classification of the plutonic rocks associated with PME skarns in British Columbia, plotted on normative diagrams of Streckeisen and Le Maitre (1979).

A = Hedley camp (data from Ray *et al.*, 1988).

B = Tillicum Mountain camp (unpublished data from Ray).

C = Ten other PME skarn areas in British Columbia (data from Appendix 6).

Sulphide minerals observed in skarn at the Discovery deposit include pyrrhotite, pyrite, arsenopyrite, sphalerite and chalcopyrite. The pyrrhotite forms small masses, whereas pyrite, arsenopyrite, sphalerite and chalcopyrite occur as both thin veinlets and fine disseminations.

Two types of gold mineralization are observed in diamond-drill core. The first is associated with the massive pyrrhotite that replaces marble. The pyrrhotite contains up to 1 per cent pyrite with trace amounts of chalcopyrite. The gold appears to be directly associated with the pyrrhotite which yields assays exceeding 100 grams gold per tonne over a 2-metre intercept. The second type is hosted by a brecciated quartz-pyrite vein filling a fracture zone that crosscuts the garnet skarn and marble. Massive white to medium grey quartz with coarse pyrite is brecciated and sometimes cemented by a quartz-carbonate matrix. Vuggy quartz commonly fills voids left by the oxidation and removal of pyrite. There is a possible genetic link between skarn and the quartz-pyrite vein mineralization; both contain anomalous gold values, and the breccia textures and quartz-carbonate cement indicate a complex hydrothermal history.

In contrast, skarn at the Bob deposit, approximately 4 kilometres northwest of the Discovery zone (Figure 38), is less extensive and occurs primarily within a stock of tonolitic composition (Figure 39C). Endoskarn consists of garnet, pyroxene and chlorite with minor amphibole, epidote, pyrite and arsenopyrite. The garnets are more iron rich than at the Discovery zone, ranging in composition from Ad 45 to Ad 53 mole per cent (Figure 23F). Pyroxene varies in composition from Hd 14 to Hd 49 per cent and exhibits weaker zoning, with only a slight increase in iron content towards the rim (Figure 25E).

Gold-silver mineralization is primarily contained in the Bob zone, an east trending structure that cuts the tonalite. Intense sericite alteration spatially associated with quartz-pyrite veins contains minor arsenopyrite, chalcopyrite and gold mineralization. Gold values up to 2.9 grams per tonne gold are also present outside this zone, in the fractured tonalite.

CHAPTER 6

MINERALOGY, GEOCHEMISTRY AND CHARACTERISTICS OF PME SKARNS AND THEIR ASSOCIATED INTRUSIONS

CHARACTERISTICS OF INTRUSIONS ASSOCIATED WITH PME-SKARNS

Ray *et al.* (1988) noted that the gold-bearing skarns in the Hedley and Tillicum Mountain camps are associated with subalkalic, calc-alkaline, I-type intrusions (Figures 40A and 40B; 41A and 41B) and this appears to be also true for most of the other PME skarns in British Columbia (Figures 40C and 41C). Major element oxide data from unaltered intrusions spatially associated with PME skarns in nine areas are presented in Appendix 6 together with the CIPW norms; analytical data and CIPW norms of the skarn-related intrusions in the Hedley and Tillicum Mountain camps are presented by Ray *et al.* (1988). In most of the 11 areas studied, where endoskarn has developed, the skarn-related plutons can be identified with confidence although the genetic relationship between skarn and pluton at a few other locations is less certain.

The CIPW normative mineralogies presented in Appendix 6 and and in Ray *et al.* (1988) and plotted in Figures 39A, 39B and 39C show that PME-skarn mineralization throughout the province is associated with a wide variety of intrusive rocks ranging from granite to gabbro, although quartz diorite to diorite appears to predominate. Despite this province-wide variation in composition, the skarn-related intrusions are consistently subalkalic (Figures 40A, 40B and 40C) and usually calc-alkaline (Figures 41A, 41B and 41C) although iron-enriched tholeiitic material is present at the Zeballos and Merry Widow skarns; these restricted tholeiitic compositions may be related to the iron-skarn affinities of the Zeballos and Merry Widow deposits.

In some gold-skarn camps, such as Hedley, the intrusions associated with the PME-skarn mineralization show relatively little compositional variation throughout the district (Figure 39A). In other camps, however, such as Tillicum Mountain and Texada Island, the skarn-related intrusions exhibit much wider ranges in composition (Figures 39B and 39C).

MINERALOGICAL CHARACTERISTICS OF PME SKARNS

The primary skarn mineralogies produced by a combination of metamorphic and metasomatic processes are relatively simple. However, differences in relative abundance, timing of deposition, ionic substitutions and habit of individual minerals make each skarn occurrence relatively unique and a wide variety of minerals are found in the PME skarns of British Columbia; a partial list of these minerals and their approximate paragenetic relationships are given in Table 4. Interpretation of the mineral relationships is mainly based on field and thin-section observations and on information extracted from the literature. The columns "Commonly Present", "Sometimes Present" and "Rarely Present" in Table 4 refer to the mineral distribution frequency among all the PME-skarn deposits. Consequently, if a mineral is reported at only one skarn location, it is placed under the heading "Rarely Present", irrespective of its abundance in that particular skarn.

Within many ferrous and base metal skarns individual crystals of garnet, and to a lesser extent pyroxene, commonly exhibit compositional variations from core to rim. This is illustrated in Figure 42, where compositional data from electron microprobe traverses across individual garnet crystals are presented for samples from the Mason Valley, Nevada, copper skarn (modified from Einaudi, 1977); and the King Island, Tasmania, and Cantung, Canada, tungsten skarns (modified from Kwak, 1978 and Dick and Hodgson, 1982, respectively). Apart from one garnet in the King Island skarn, the other garnets analysed exhibit progressive iron enrichment from core to rim. Myers (1985) notes that garnets in the iron-copper skarns on the Kasaan Peninsula, Prince of Wales Island, Alaska, also become more andraditic toward their rims, while Morgan (1975) describes zoned anisotropic garnet from the Scheelore mine in California as having slightly more grossular-rich cores. This may indicate a progressively oxidizing environment during garnet deposition, as sufficient Fe^{+3} becomes available to form more andradite-rich garnet.

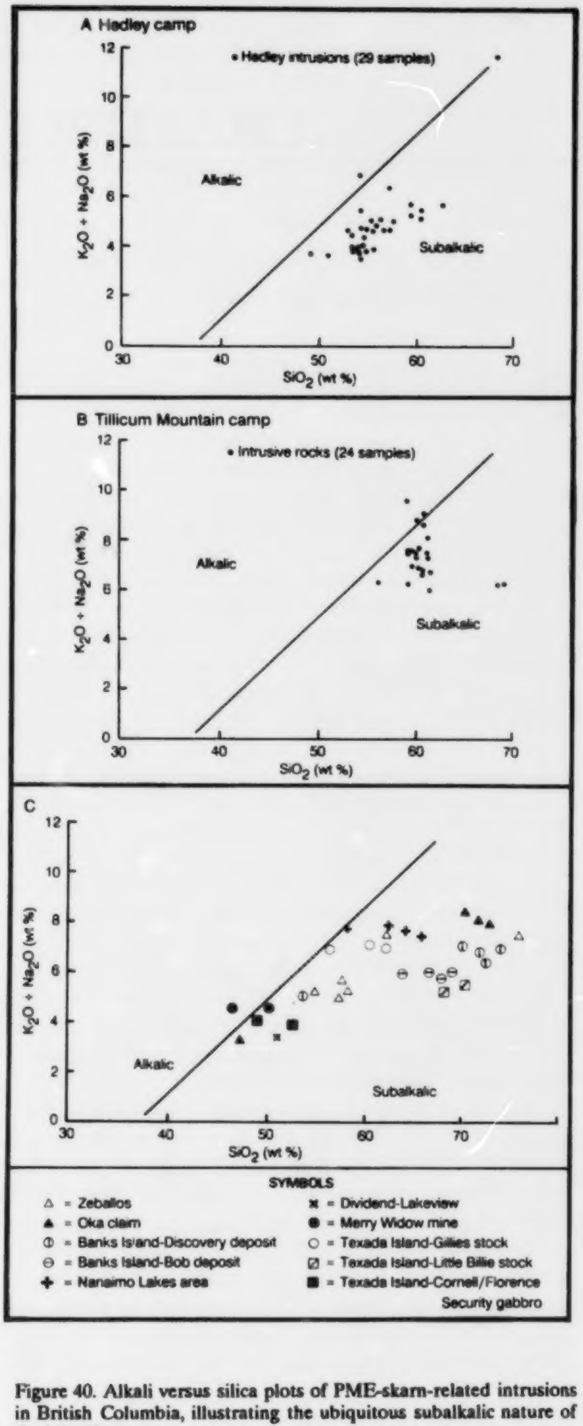


Figure 40. Alkali versus silica plots of PME-skarn-related intrusions in British Columbia, illustrating the ubiquitous subalkalic nature of the intrusions.

A = Hedley camp (after Ray *et al.*, 1988).

B = Tillicum Mountain camp (unpublished data from Ray).

C = Ten other PME-skarn areas in British Columbia (data from Appendix 6).

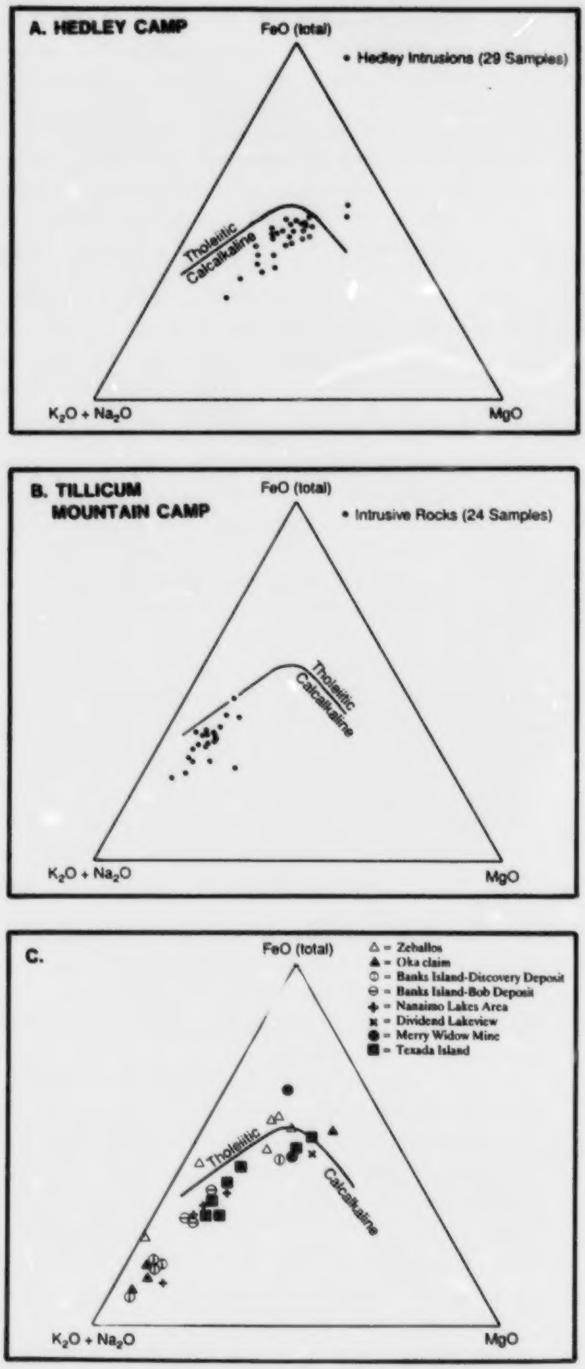


Figure 41. AFM diagrams (after Irvine and Baragar, 1971) showing the predominantly calc-alkaline trends of the intrusive rocks associated with PME-skarns in British Columbia.

A = Hedley camp (data from Ray *et al.*, 1988).

B = Tillicum Mountain camp (unpublished data from Ray).

C = Eight other PME-skarn areas in British Columbia (data from Appendix 6).

TABLE 4
PME-SKARN MINERALOGY
APPROXIMATE PARAGENESIS AND RELATIVE ABUNDANCES

RELATIVE ABUNDANCE Timing:	COMMONLY PRESENT	SOMETIMES PRESENT	RARELY PRESENT
Early	clinopyroxene garnet biotite quartz calcite magnetite wollastonite idocrase*	scapolite apatite* sphene*	axinite* tourmaline*
Intermediate	clinopyroxene garnet microcline anorthite albite* quartz calcite pyrite* pyrrhotite*	prehnite wollastonite apatite* sphene* Cl-rich amphibole* sericite* chalcopyrite* marcasite*	scheelite* anthophyllite* molybdenite*
Late	clinozoisite epidote tremolite ferro-actinolite chlorite calcite garnet quartz clay scapolite prehnite magnetite pyrite chalcopyrite pyrrhotite marcasite limonite	hornblende ferro-edenitic hornblende hastingsitic hornblende zoisite* hematite arsenopyrite erythrite* cobaltite* electrum sphalerite hedleyite bismuthinite maldomite native gold, bismuth azurite malachite	talc humite* scheelite* bornite galena chalcocite molybdenite tennantite* cuprite* native copper, silver cobaltite erythrite* graphite* tetrahedrite* tetradymite* pearcite* pyrargyrite* hessite*

*Timing uncertain.

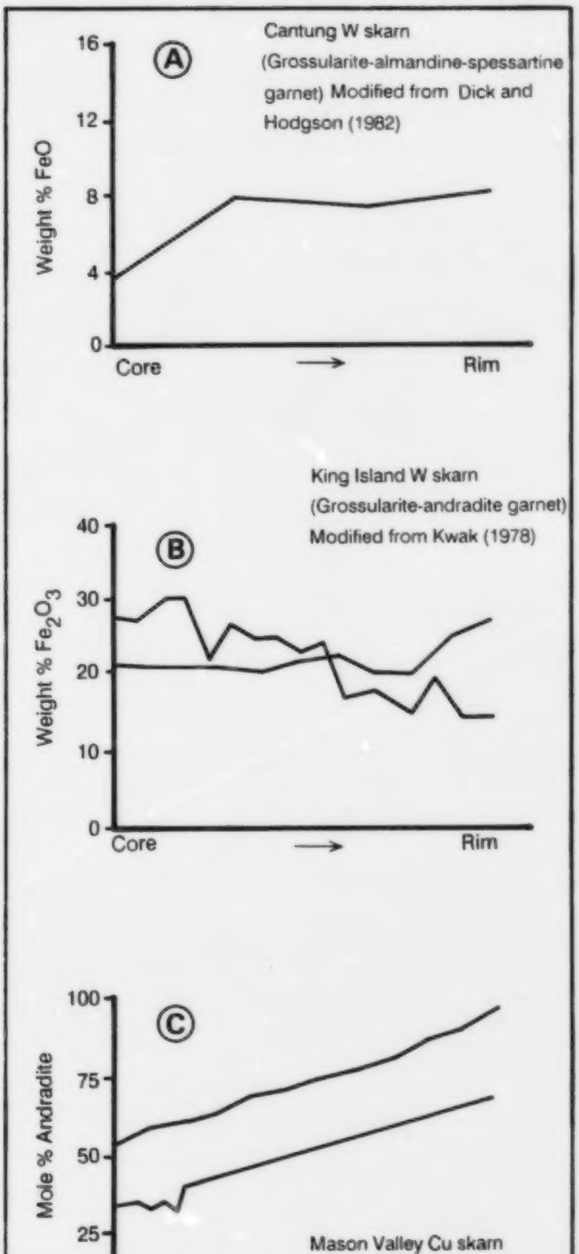


Figure 42. Compositional variations across individual garnet crystals in:
(a) Cantung tungsten skarn.
(b) King Island tungsten skarn.
(c) Mason Valley copper skarn.

For comparison, the compositional variations of mole per cent andradite across individual garnet crystals from 10 PME skarns in British Columbia are shown in Figures 43A to 43J. Garnets at the Nickel Plate, French, Goodhope and Canty mines in the Hedley district show little overall compositional change from core to rim. By contrast garnets from the Peggy, Merry Widow, Oro Denoro and Phoenix mines, and from Mount Riordan, generally display aluminous margins. The garnets at the Dividend-Lakeview and Merry Widow mines (Figures 43G and 43H) have cores with highly variable compositions (Ad 25 to Ad 100) while the rims and intermediate portions of the crystals have less varied compositions. This suggests that the initial garnet nucleation and early crystal growth is strongly influenced by local variations in protolith composition. Thus, nucleation sites at or adjacent to iron-poor phases, such as plagioclase or quartz, produce andradite-poor cores relative to nucleation sites near iron-rich phases, such as amphibole and pyroxene. However, once the garnet crystal is nucleated, the overall fluid chemistry and physical conditions dominate the composition of successive growth zones more than original protolith chemistry. The small range in intermediate compositions in the Dividend-Lakeview garnets probably reflects the existence of stable physical conditions and a common fluid source during most of the garnet growth. The iron enrichment in the garnet rims may indicate a sudden change in physical conditions and fluid composition within the hydrothermal system. These changes may have been coeval with, or responsible for, the late deposition of the sulphides and precious metals.

Pyroxene crystals from these skarns, unlike garnets, do not generally exhibit marked core to rim compositional variations, although those from the Discovery deposit on Banks Island are exceptional and contain pure diopside cores that change progressively outward to hedenbergite-rich margins (Figure 25E). Electron microprobe traverses across some pyroxene crystals indicate the presence of aluminum enrichment which is mostly confined to specific narrow growth zones in the crystal (Figure 44B). It is possible that the presence of pyroxenes with a high alumina content may be an indicator of enhanced precious metal potential. The Al_2O_3 + TiO_2 versus FeO content of pyroxenes from several different types of skarn mineralization are presented in Figure 45. These figures suggest that for certain levels of FeO, PME-skarn pyroxenes are sporadically enriched in Al_2O_3 + TiO_2 compared to pyroxenes in ferrous and base metal skarns; a value exceeding 1.25 weight per cent Al_2O_3 + TiO_2 in pyroxenes is regarded as anomalous, and may indicate a particular skarn has precious metal potential.

The different pyroxene compositional fields (Al_2O_3 + TiO_2 versus FeO) for PME skarns, and ferrous and base metal skarns are outlined in Figures 46A and 46B, respectively. A combination of these is illustrated in

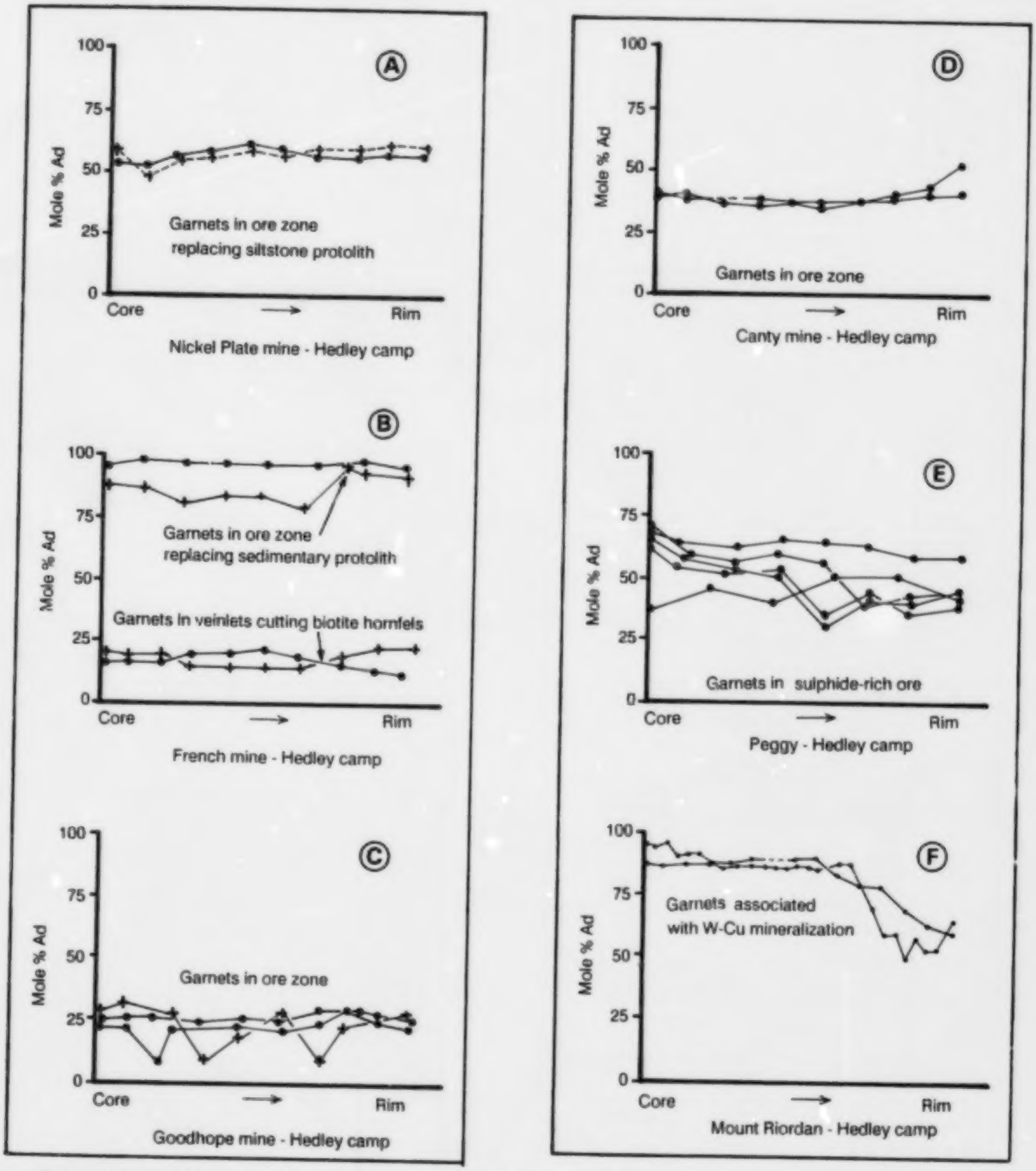


Figure 43. Compositional variation (in mole per cent andradite) across individual garnet crystals from some PME skarns in British Columbia. (Analyses A to F by G.E. Ray and G.L. Dawson at The University of British Columbia, Vancouver; analyses G to J by A.D. Ettlinger at Washington State University, U.S.A.)

A = Nickel Plate mine, Hedley camp.
B = French mine, Hedley camp. (Note contrasting compositions between garnets in ore zone and garnets in the outer part of the skarn envelope.)
C = Goodhope mine, Hedley camp.
D = Canty mine, Hedley camp.
E = Peggy, Hedley camp.
F = Mount Riordan, Hedley camp.
G = Dividend-Lakeview mine.
H = Merry Widow mine.
I = Greenwood camp.
J = Nanaimo Lakes.

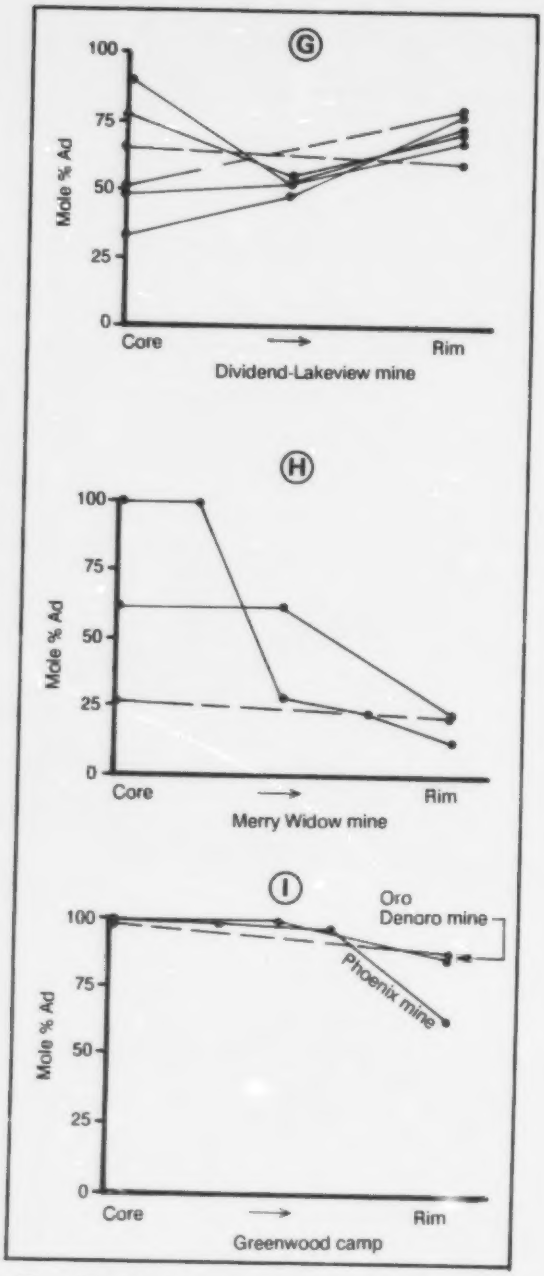


Figure 43 continued.

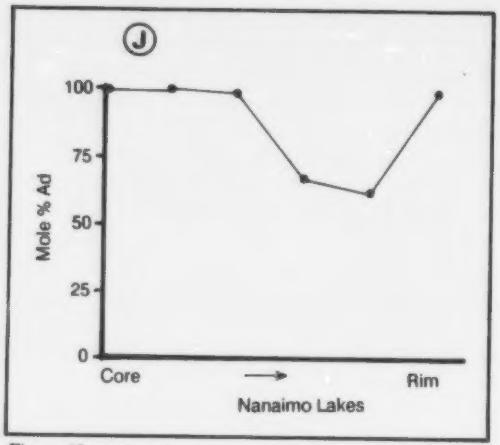


Figure 43 continued.

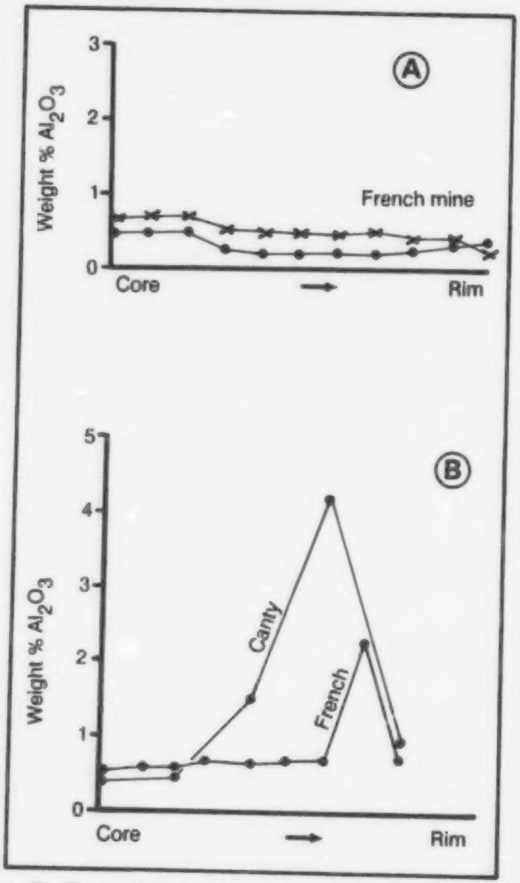


Figure 44. Compositional variation (in weight per cent Al_2O_3) across individual pyroxene crystals from the French and Canty mines, Hedley camp. Generally, most PME-skarn pyroxenes exhibit very little variation in alumina as seen in Figure 44A. However, in some PME skarns, rare, individual pyroxenes contain narrow zones of aluminum enrichment as seen in Figure 44B. (Analyses by G.E. Ray and G.L. Dawson at The University of British Columbia, Vancouver.)

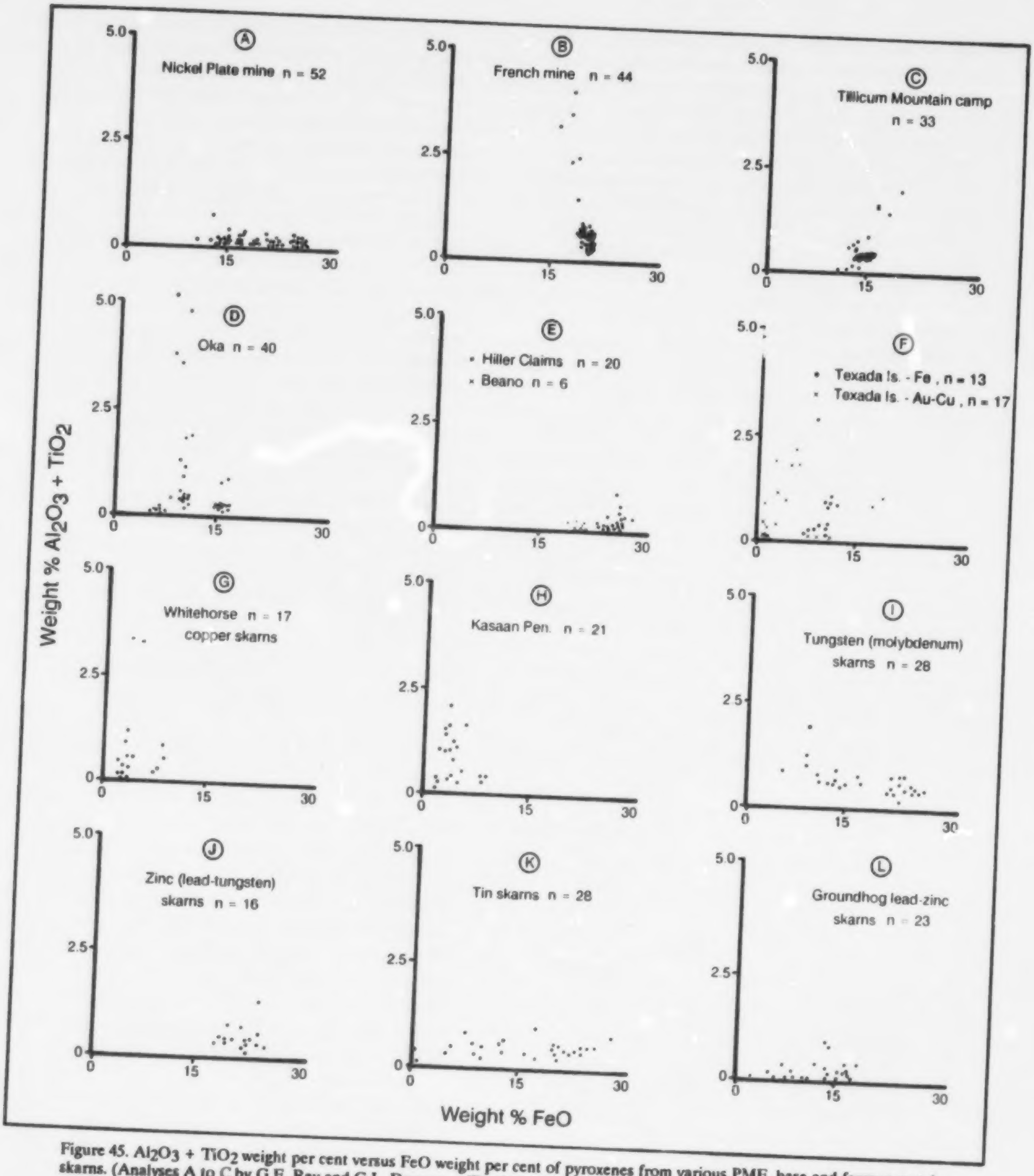


Figure 45. $Al_2O_3 + TiO_2$ weight per cent versus FeO weight per cent of pyroxenes from various PME, base and ferrous metal skarns. (Analyses A to C by G.E. Ray and G.L. Dawson at The University of British Columbia, Vancouver; analyses D to F by A.D. Ettlinger at Washington State University, U.S.A.)

A = Nickel Plate mine, Hedley camp.
B = French mine, Hedley camp.
C = Tillicum Mountain camp.
D = Oka claims.
E = Hiller claims.
F = Texada Island camp (iron skarns = dots; gold-copper skarns = crosses).
G = Whitehorse copper skarns (after Morrison, 1981).
H = Kasaan Peninsula (after Myers, 1985).
I = Tungsten (molybdenum) skarns (after Dick, 1980).
J = Zinc (lead-tungsten) skarns (after Dick, 1980).
K = Tin skarns (after Dick, 1980).
L = Groundhog lead-zinc skarns (after Meinert, 1987b).

Figure 46C which identifies three pyroxene compositional fields; one characterizes some PME skarns and indicates a high gold-silver potential, while the second field characterizes base and ferrous metal skarns and suggests a low precious metal potential. The third field (Figure 46C) is common to PME, base and ferrous metal skarns; thus pyroxenes falling in this compositional field cannot be used to indicate the precious metal potential of a skarn. However, it should be noted that no high alumina pyroxenes have been discovered in the Nickel Plate deposit; the pyroxenes in this skarn fall within the third, indeterminate field (Figure 45A). By contrast, the French, Tillicum Mountain and Oka gold skarns contain some pyroxenes with markedly alumina-rich zones (Figures 45B, 45C and 45D, respectively), as do the skarns at the McCoy mine near Battle Mountain, Nevada, where this enrichment was first recognized (J. Brooks, personal communication, 1988). Thus, pyroxene analysis for Al_2O_3, TiO_2 and FeO may aid PME-skarn exploration although it cannot conclusively isolate a target such as the Nickel Plate deposit. Its other main disadvantage as a technique for target evaluation is that it requires numerous core to rim electron microprobe analyses of the pyroxenes, because the significant aluminum enrichment is confined to very narrow growth zones that could easily be missed during random spot analysis.

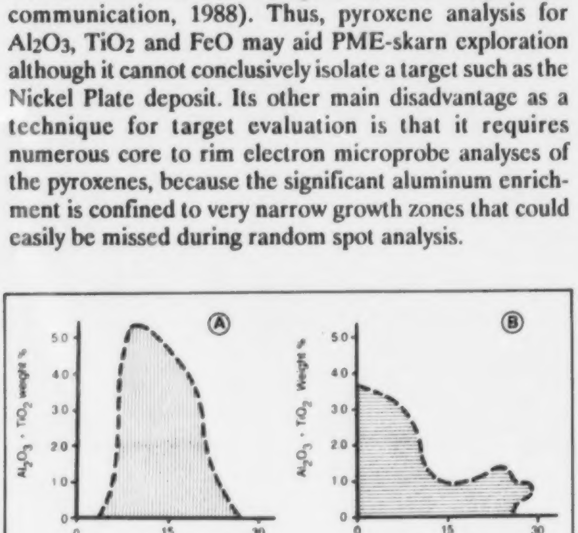


Figure 46. Pyroxene compositional fields (Al_2O_3 + TiO_2 versus FeO) for:
A = PME skarns.
B = Base and ferrous metal skarns.
C = Combination of compositional fields outlined in A and B indicating pyroxene fields with high, low and indeterminate gold-silver potential. Data for fields derived from Figure 45.

In summary, the available data on compositio zoning in garnet crystals from ferrous and base me skarns indicate a general increase in iron content towa the crystal rim. Data from garnets in PME skarns, ho ever, suggest no similar overall pattern and many cryst contain growth zones marked by iron depletion. A c responding increase in aluminum occurs in these zo resulting from the complete solid solution between i (andradite) and aluminum (grossularite) end-membe The aluminum-iron zoning in garnets and the relat aluminum enrichment in some pyroxenes from PM skarns suggest a relationship between deposition of aluminum and the precious metals. Two explanations possible: since aluminum in the skarn-forming fluid mainly taken up by grossularitic garnet, periods of i enrichment in the garnets would increase the amoun aluminum in solution and subsequently force so aluminum into the pyroxene structure. Alternativ within any single PME-skarn deposit, specific zones aluminum enrichment in garnets and pyroxenes may h developed coevally and thus could represent period increased total aluminum or decreased alumi solubility in the hydrothermal system. In both ca however, the primary gangue minerals hosting the g silver mineralization could exhibit sporadic alumin enrichment.

TRACE ELEMENT GEOCHEMISTRY OF SOME PME SKARNS

Trace element analyses from 76 samples were c pleted at the Ministry of Energy, Mines and Petrole Resources Analytical Sciences Laboratory. The res are presented in Appendix 7. These samples were lected from 13 properties representing either gold-be ing skarns (for example, Oka and Dividend-Lakevie PME copper skarns (for example, Phoenix) or PME skarns (for example, Texada Iron Mines, Oro Deno Most grab samples were collected from skarn outcr open-pit exposures or diamond-drill core; however, comparison, a few analyses are included from unmine ized hostrocks or associated intrusions. Brief sam descriptions follow the data at the end of Appendix 7

Derivations of the results for gold, silver, cop lead, zinc, cobalt, arsenic and bismuth analyses are sh graphically on the scatter diagrams in Figure 47. Onl samples returned detectable levels of molybdenum therefore the molybdenum data is not included in th diagrams. The approximate linear relationship betw elemental pairs is represented by the least squares bes curve drawn on each scatter plot. The correlation co cients for each of these curves, together with the num of samples used in each calculation, are presente Table 5. Due to the limited database available at this ti results from all samples returning detectable levels of the plotted elements are incorporated into the diagrams. Multiple geologic processes may be responsible for some of the observed relationships.

At the 95 per cent confidence level, all correlations are significant except for: bismuth with silver, lead, zinc, cobalt and arsenic, and lead with gold and copper. The highest correlations occur between Ag:Cu (0.73), Ag:Zn (0.72), Co:As (0.63), Pb:As (0.57), Cu:Zn (0.56), Cu:Co (0.56) and Au:Bi (0.51). Of the significant correlations, only Cu:Bi exhibits an inverse relationship (-0.50).

The majority of these correlations can be accounted for by the mineral assemblages commonly encountered in the skarn deposits studied. Figure 48 is a linear correlation diagram which illustrates the possible relationships between elemental correlations and observed mineralogies. The strong association between silver, zinc and copper probably reflects the tendency of sphalerite, if present in the skarn, to be associated with chalcopyrite. This type of mineralization, which is typically later than the prograde skarn alteration assemblage, returned analyses up to 200 ppm silver (Appendix 7). There is a weaker correlation between the silver-zinc-copper mineralization and gold. This is probably due to a combination of the high correlation existing between gold and chalcopyrite-rich ore in the iron skarns (for example, Merry Widow) and the much lower gold to copper correlation that is present in the true gold skarns such as the Nickel Plate deposit.

Moderate to high positive correlations exist between Co:As, As:Pb and to a lesser extent, Pb:Co. Cobaltite (CoAsS), which is a common minor constituent in iron skarns and occurs in significant concentrations at the Nickel Plate and TP gold skarns, is partially responsible for the strong Co:As association. Electron microprobe analyses indicate that some arsenopyrite in the Nickel Plate deposit contains up to 4.2 weight per cent cobalt, which also contributes to the observed Co:As relation-

TABLE 5
TRACE ELEMENT CORRELATION MATRIX OF PME SKARN DATA LISTED IN APPENDIX 7

	Au	Ag	Cu	Pb	Zn	Co	As	Bi
Au	x	*0.33*	*0.37*	0.28	*0.28*	*0.39*	*0.43*	*0.51*
Ag	*0.33*	x	*0.73*	*0.33*	*0.72*	*0.47*	*0.45*	-0.25
Cu	*0.37*	*0.73*	x	0.14	*0.56*	*0.56*	*0.47*	*-0.50*
Pb	0.28	*0.33*	0.14	x	*0.26*	*0.36*	*0.57*	0.46
Zn	*0.28*	*0.72*	*0.56*	*0.26*	x	*0.33*	*0.29*	-0.13
Co	*0.39*	*0.47*	*0.56*	*0.36*	*0.33*	x	*0.63*	0.24
As	*0.43*	*0.45*	*0.47*	*0.57*	*0.29*	*0.63*	x	0.18
Bi	*0.51*	-0.25	*-0.50*	0.46	-0.13	0.24	0.18	x

Significant numbers in italics.

Number of samples

	Au	Ag	Cu	Pb	Zn	Co	As	Bi
Au	x	44	51	46	51	49	50	23
Ag	44	x	48	44	48	44	46	21
Cu	51	48	x	71	76	69	71	23
Pb	46	44	71	x	71	64	66	18
Zn	51	48	76	71	x	69	71	23
Co	49	44	69	64	69	x	66	23
As	50	46	71	66	71	66	x	23
Bi	23	21	23	18	23	23	23	x

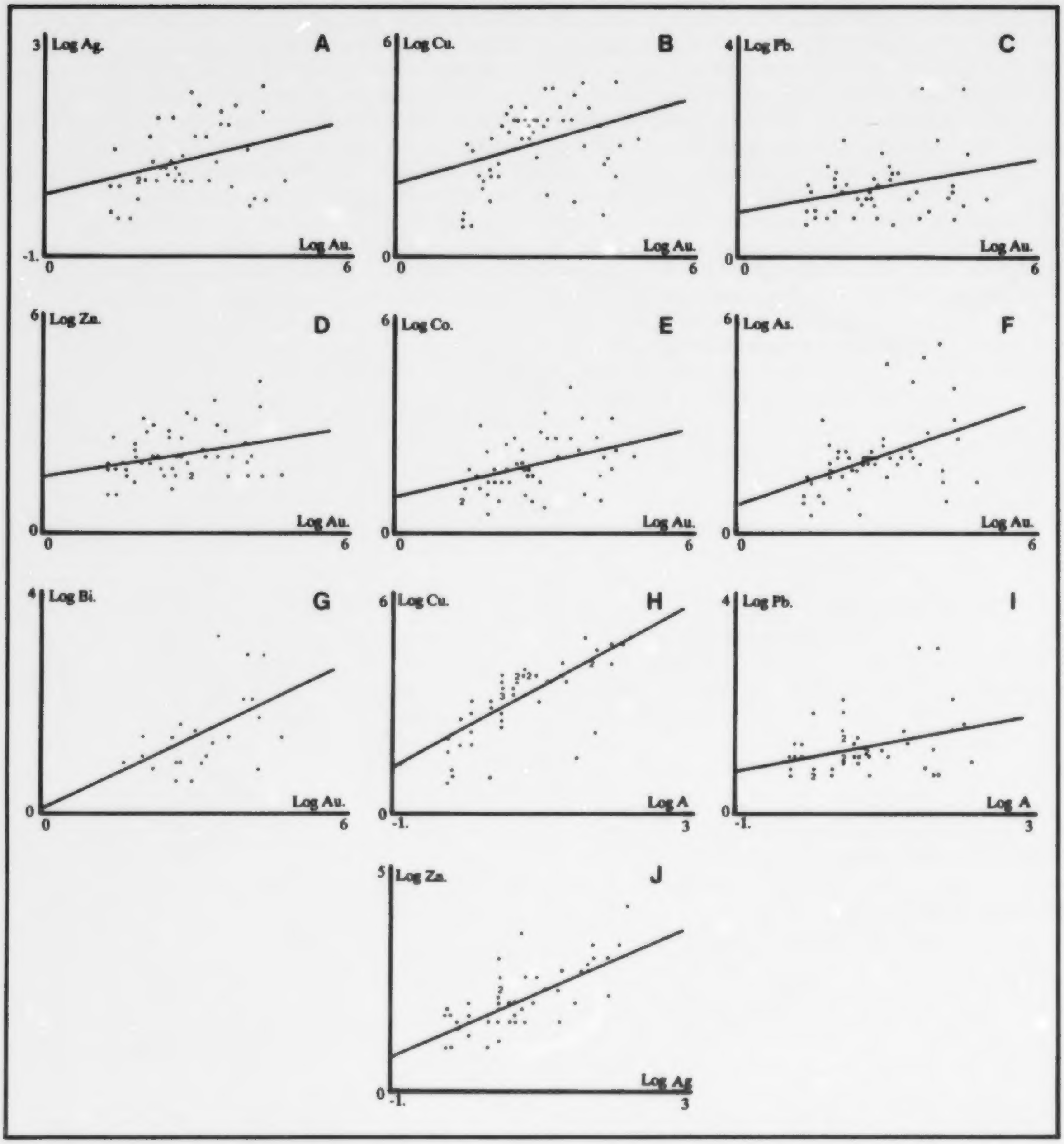
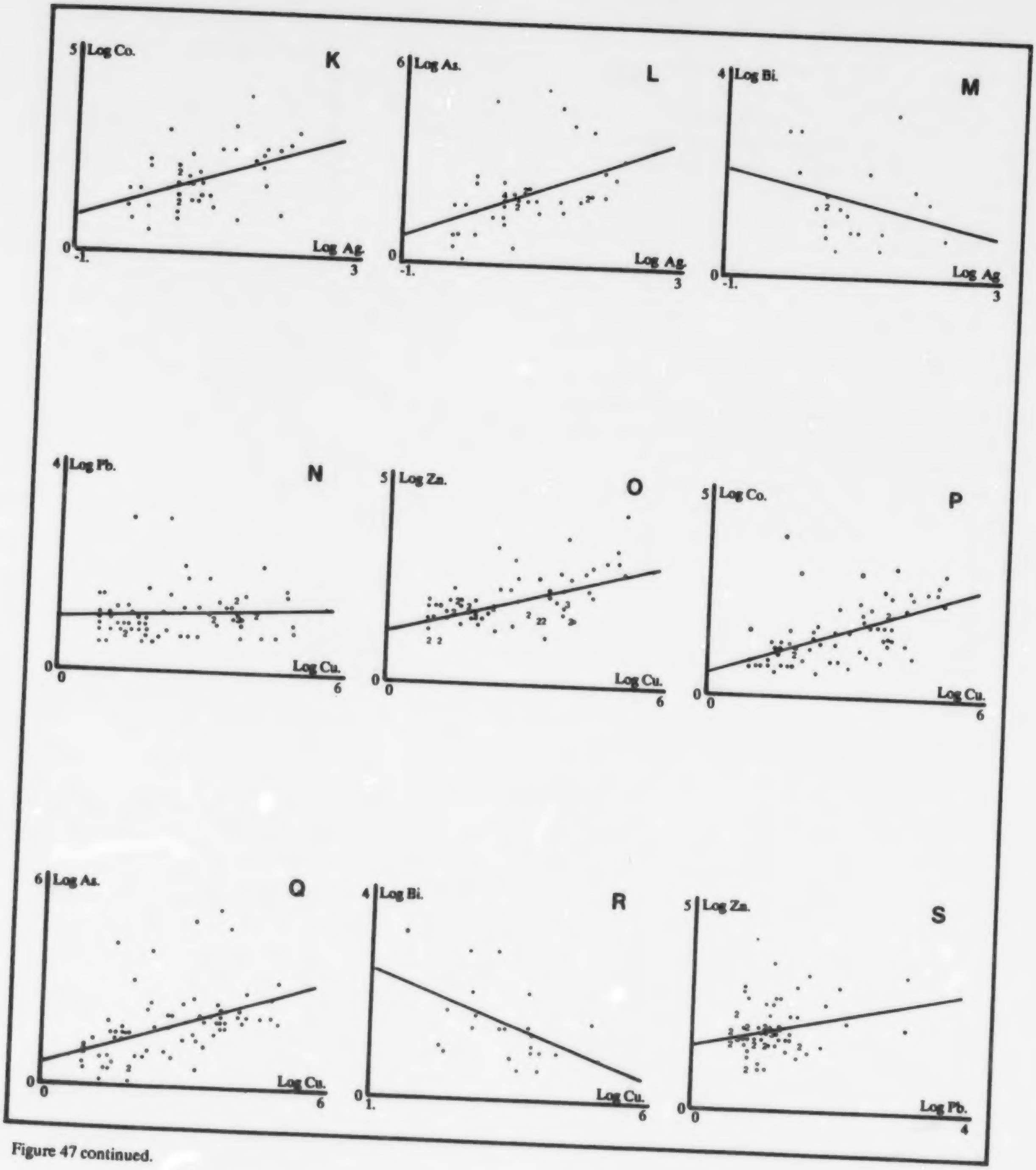


Figure 47. Scatter plots with linear regression "best-fit" curves for trace elements listed in Appendix 7. (The symbols 2 and 3 on the scatter plots refer respectively to two or three closely spaced or overlapping dots.) *See* Table 5 for correlation coefficients and sample populations.



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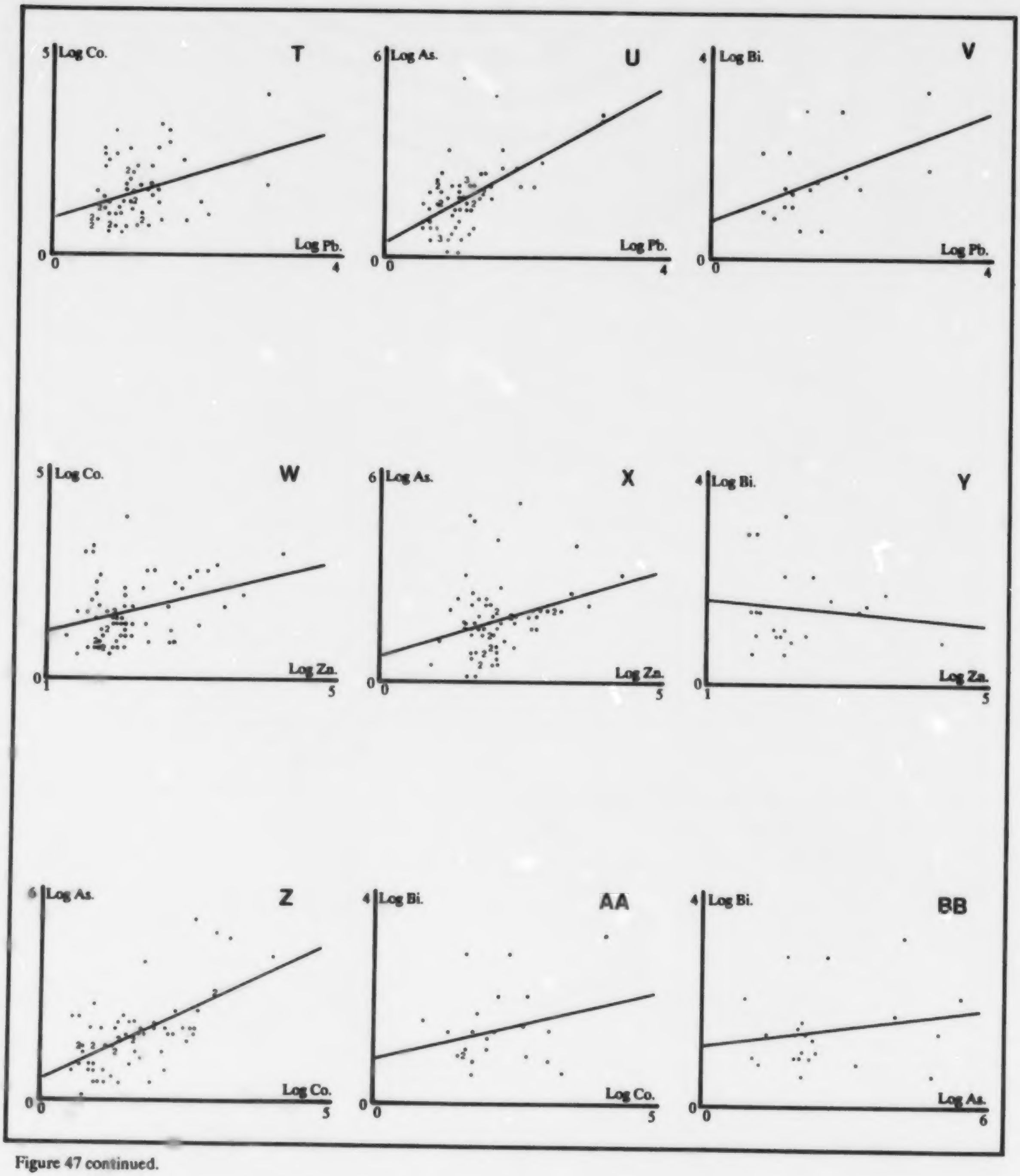

Figure 47 continued.

ship. The reason for the significant correlation between Pb:As and Pb:Co is uncertain. Although the arsenopyrite at the TP skarn contains micron-sized blebs of galena, this study suggests that galena is rare in most gold-enriched skarns in British Columbia and that consequently the lead content of these deposits is generally very low. Divalent lead has a large ionic radius in relation to cobalt and arsenic and it is unlikely that significant substitution results between lead and these two elements.

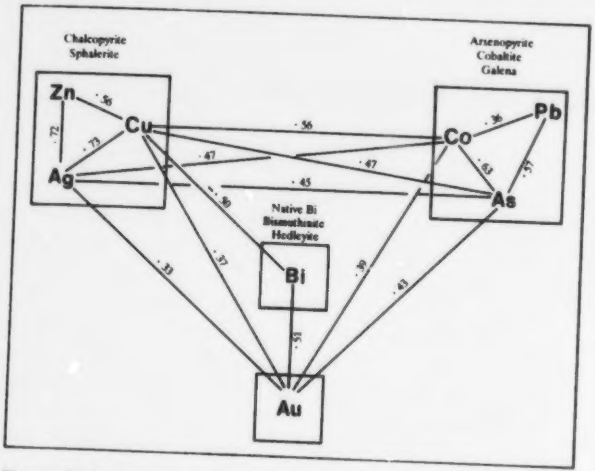

Figure 48. Linear correlation diagram showing moderate and strong correlations for trace elements presented in Appendix 7 and Table 5.

Gold exhibits a moderate correlation with the cobalt-arsenic-lead group, having significant coefficients for cobalt and arsenic (r=0.39, n=49 and r=0.43, n=50, respectively). A similar correlation is reported for a large (300) mineralized sample population in the Nickel Plate orebody (Ray *et al.*, 1988). This is supported by ore microscopy which shows native gold grains locally enclosed by arsenopyrite in the Nickel Plate and Dividend-Lakeview deposits, and by cobaltite at the TP claims.

The highest elemental correlation with gold is for bismuth (0.51). This is also the only significant positive correlation bismuth exhibits with any other element analysed (Table 5). Ray *et al.* (1988) report a Au:Bi correlation coefficient of 0.94 for the Nickel Plate deposit which results from the consistent occurrence of hedleyite (Bi_7Te_3), bismuthinite (Bi_2S_3) and native bismuth with gold in the Nickel Plate system. These relationships are also observed, but to a lesser extent, at the Dividend-Lakeview mine and the Hiller and TP skarns.

CHAPTER 7

PROBLEMS IN CLASSIFYING PME SKARNS

Despite the 60-year history of gold production from the skarns in the Hedley camp, gold skarns have only very recently become widely recognized in the literature as a distinct class of skarn deposit (for example, Meinert, 1987a; Orris *et al.*, 1987). Gold skarns are neither examined nor defined in the classical paper by Einaudi *et al.* (1981), which outlines the six major classes of ferrous and base metal skarns (Fe, Cu, W, Pb-Zn, Mo and Sn), or in the geological synopsis of Canadian mineral deposits by Eckstrand (1984). One probable reason for this is that gold skarns are difficult to classify in relation to base and ferrous metal skarns which can be categorized using a number of criteria (Einaudi *et al.*, 1981) including the predominant base metal present and the alkali versus silica compositions of the associated intrusive rocks (Meinert, 1983). However, ferrous and base metals are usually present in skarns in percentage quantities while gold is a high value metal that generally only reaches concentrations of a few parts per million. Thus small changes in gold concentration, together with price variations of the base, ferrous or precious metals, can progressively alter the classification of a deposit from an end-member ferrous or base metal skarn to an end-member gold skarn.

The inability to categorize gold skarns using conventional ferrous and base metal classifications is illustrated in Figure 49. Alkali versus silica plots of the skarn-related intrusions from the Hedley and Tillicum Mountain gold skarn camps are shown in relation to the relevant compositional fields for iron, copper and tungsten skarn-related intrusions as defined by Meinert (1983). The Hedley intrusions fall largely within the iron-skarn field (Figure 49A) even though both mineralogical and geochemical evidence shows that the Hedley deposits are not true iron skarns. By contrast, the Tillicum Mountain rocks fall largely within the copper-skarn field (Figure 49B) although the Tillicum Mountain gold skarns are not copper rich. However, it is notable that many PME skarns are commonly found in the same geological environment as iron and copper skarns and copper porphyries, and a continuum probably exists between end-member gold skarns such as the Nickel Plate deposit, and end-member copper and iron skarns with little or no precious metal enrichment. Compared to copper skarns, iron skarns tend to have less overall gold enrichment. If present, however, gold is usually concentrated in relatively small, isolated areas of the deposit where the magnetite ore is sulphide and copper rich. While gold is sufficiently enriched in many copper skarns to provide a major economic support to the mining operation (for example, Phoenix mine), in

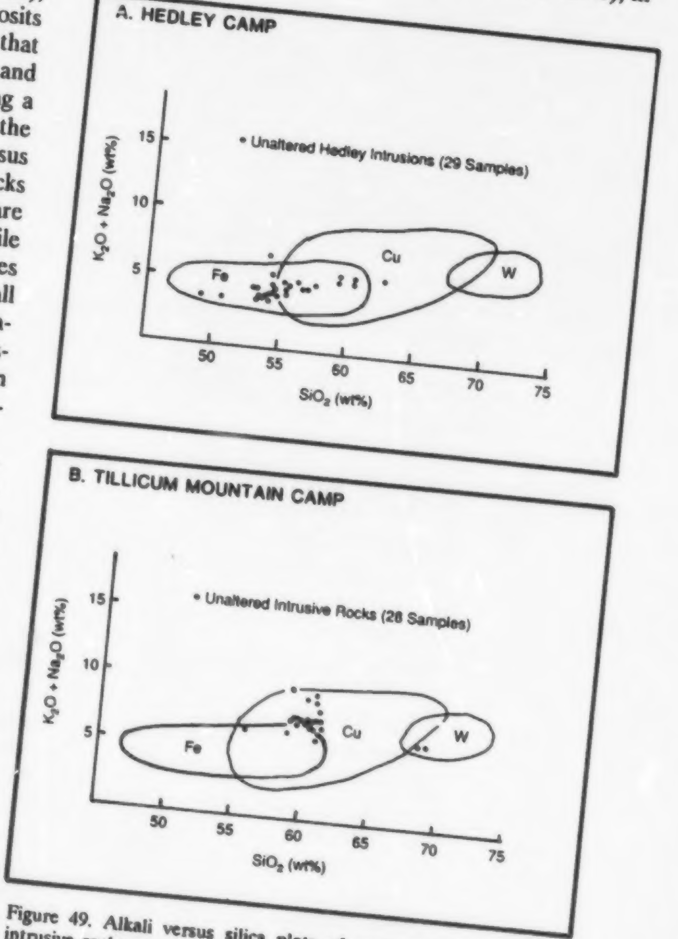

Figure 49. Alkali versus silica plots of some PME-skarn-related intrusive rocks compared to iron, copper and tungsten skarn class boundaries as outlined by Meinert (1983).
A = Hedley camp (after Ray *et al.*, 1988).
B = Tillicum Mountain camp (unpublished data from Ray).

TABLE 6
Cu/Au AND Cu/Ag RATIOS OF REPORTED GOLD SKARNS WORLDWIDE

NO. IN FIG. 50	NAME	Cu/Au	Cu/Ag	REFERENCE OR DATA SOURCE
1	Hedley Mascot, B.C.	125	510	Production data (*see* Appendix 1*).
2	Nickel Plate, B.C. (underground)	23	235	Production data (*see* Appendix 1*).
3	Nickel Plate, B.C. (open pit)	222	333	Mascot Gold Mines information, Sept. 1987.
4	Browns Creek, Australia	533	444	Taylor (1983); Meinert (1987a) (*see* Table 1).
5	Cable, Montana	5000	6000	Holser (1950); Earll (1972) (*see* Table 1).
6**	Fortitude, Nevada	144	40	Blake *et al.* (1984); Wotruba *et al.* (1986) (*see* Table 1).
6	Fortitude, Nevada	200	56	Meinert (1987a).
7	Minnie-Tomboy, Nevada	357	111	Blake *et al.* (1984); Meinert (1987a).
8	Red Dome, Australia	2300	1000	Torrey *et al.* (1986) (*see* Table 1).
9	Surprise, Nevada	2500	372	Benson, quoted as pers. comm. in Meinert (1987a).
10	Northeast Extension, Nevada	379	73	Wotruba *et al.* (1986); Orris *et al.* (1987).
11	Pagaran Siayu, Indonesia	357	800	Bowles *et al.* (1985); Orris *et al.* (1987).
12	Thanksgiving, Philippines	162	35	Callow (1967); Bryner (1969); Meinert (1987a).
12**	Thanksgiving, Philippines	625	98	Orris *et al.* (1987) (*see* Table 1).
13	Southern Cross, Montana	76	62	Earll (1972); Orris *et al.* (1987) (*see* Table 1).
14	Salsione, France	115	45	Elevatorski (1981); Meinert (1987a).
15	Golden Curry, Montana	388	785	Roby *et al.* (1960); Orris *et al.* (1987) (*see* Table 1).
16	La Luz (Suinna), Nicaragua	1073	3666	Plecash *et al.* (1963); Sillitoe (1983); Orris *et al.* (1987) (*see* Table 1).

*Data in Table 1 for combined Hedley-Mascot and Nickel Plate (underground) give following ratios: Cu/Au = 71; Cu/Ag = 714.

Note: Metal ratios for Nos. 6 and 12** not included in Figure 50.

TABLE 7
Cu/Au AND Cu/Ag RATIOS OF REPORTED COPPER SKARNS WORLDWIDE

NO. IN FIG. 50	NAME	Cu/Au	Cu/Ag	REFERENCE OR DATA SOURCE
17	Clifton District, Utah.	33333	213	Quoted by Meinert (1987a).
18	Frankie, Utah.	23529	1270	Quoted by Meinert (1987a).
19	Geo/Star, B.C.	24000	2118	Quoted by Meinert (1987a).
20	Moncocco, Utah.	33333	211	Quoted by Meinert (1987a).
21	Phoenix, B.C.	8182	1267	Table 1, production data quoted by Church (1986).
22	Phoenix, B.C.	12000	800	Production data quoted by Meinert (1987a).
23	Rosita, Nicaragua.	17778	2667	Production data quoted by Meinert (1987a).
24	Victoria, Nevada.	79000	1692	Production data quoted by Meinert (1987a).
25	Whitehorse Cu District, Y.T.	19821	1568	Production data quoted by Meinert (1987a).
26	Yaguki, Japan	2666	51	Production data quoted by Meinert (1987a).
27	Copper Queen, Texada Is., B.C.	3851	509	Appendix 1, production data quoted by Peatfield (1987).
28	Zackly, Alaska	4909	900	Production data quoted by Meinert (1987a).
29	Cornell, Texada Is., B.C.	2906	623	Appendix 1.
30	Little Billie, Texada Is., B.C.	2256	683	Appendix 1.
31	Marble Bay, Texada Is., B.C.	4397	537	Appendix 1.

iron skarns it is generally much lower grade and only recovered as an incidental byproduct.

In British Columbia gold enrichment at economically recoverable grades is relatively unusual in tungsten, lead and zinc skarns, and apparently nonexistent in the tin and molybdenum skarns. However, the gold-sphalerite-galena mineralization in the Tillicum Mountain camp and gold-scheelite mineralization in parts of the Hedley camp (French and Goodhope mines) suggests that tungsten, lead and zinc skarn districts cannot be ignored as exploration targets for precious metal deposits. Gold-tungsten-enriched skarns are reported, for example, in the Yukon (Brown, 1985), Japan (Shimazaki, 1980) and the U.S.S.R. (Khasanov, 1982; Stepanov *et al.*, 1976).

Orris *et al.* (1987) have examined the grades and tonnages of some gold-bearing skarns and have designed a useful classification in which the deposits were subdivided into "gold skarns" and "byproduct-gold skarns". By their definition, both subclasses contain 1 ppm gold or more, but the former were exploited primarily for gold, while the latter subclass include skarns mined primarily for base or ferrous metals, but where significant amounts of gold were obtained as a byproduct. However, this classification is designed primarily for producing deposits and is unsuitable for classifying mineralized but unexploited skarn occurrences.

Another method introduced here of classifying gold, copper and iron skarns is by comparing the Cu:Ag versus Cu:Au ratios. This method has the advantage that metal ratios can be determined from either assay or production data, although using isolated grab sample assays or older production data can be unreliable. The unreliability of production figures at some older mines may be due to lack of records with regard to full metal recoveries, or to high-grading the gold-rich portions of the copper or iron-skarn orebodies, resulting in uncharacteristically high gold grades for these deposits. The Cu:Au and Cu:Ag ratios of 40 deposits from around the world, described in the literature by various authors as "gold", "copper" or "iron" skarns, are listed in Tables 6, 7 and 8; the first group includes both the Hedley Mascot and Nickel Plate underground and open-pit mines, the Red Dome deposit in Australia and the Fortitude orebody in Nevada. The Cu:Ag versus Cu:Au ratios of these deposits are plotted in Figure 50 and the main fields for gold, copper and iron skarns can be determined from the clustering of points. Deposits listed as "gold skarns" in Table 6 tend to have Cu:Ag and Cu:Au ratios less than 1000 while those described as "copper skarns" (Table 7) have Cu:Au ratios ranging mainly between 2000 and 25 000, and Cu:Ag ratios ranging from 500 to 2500. In contrast the "iron skarns" (Table 8) generally have the highest Cu:Au and Cu:Ag ratios (Figure 50), ranging from 20 000 to 160 000 and 2500 to 5000, respectively. The fields outlining the copper and iron skarns overlap, but there is an apparent separation between the gold and copper skarn fields (Figure 50).

Four deposits described in the literature and listed in Table 6 as gold skarns do not fall within the gold skarn field outlined in Figure 50; these are the Cable (No. 5), Red Dome (No. 8), Surprise (No. 9) and La Luz (No. 16). It is possible that the Red Dome deposit, for example, with its average grades of 2 grams gold per tonne and 0.46 per cent copper (Torrey *et al.*, 1986) represents a gold-enriched copper skarn, rather than a true end-member gold skarn.

Using the fields outlined in Figure 50 for gold, copper and iron skarns, the Cu:Ag versus Cu:Au ratios of 54 PME skarns in the province are plotted in Figure 51. These 54 skarns, which are included in Appendix 1 and

TABLE 8

Cu/Au AND Cu/Ag RATIOS OF REPORTED IRON SKARNS WORLDWIDE

NO. IN FIG. 50	NAME	Cu/Au	Cu/Ag	REFERENCE OR DATA SOURCE
32	Iron King, Alaska.	160000	20000	Grades quoted by Meinert (1987a).
33	It, Alaska	20000	2667	Grades quoted by Meinert (1987a).
34	Larap, Philippines.	1000	200	Production quoted by Meinert (1987a).
35	Magnetite Cliff, Alaska	13333	3200	Grades quoted by Meinert (1987a).
36	Mamie, Alaska	30166	4525	Production quoted by Meinert (1987a).
37	Mt. Andrew, Alaska	38625	2809	Production quoted by Meinert (1987a).
38	Poor Man, Alaska.	3000	1500	Grades quoted by Meinert (1987a).
39	Prince of Wales District, Alaska	29625	3656	Production quoted by Meinert (1987a).
40	Texada Iron, B.C.	30112	1130	Appendix 1.

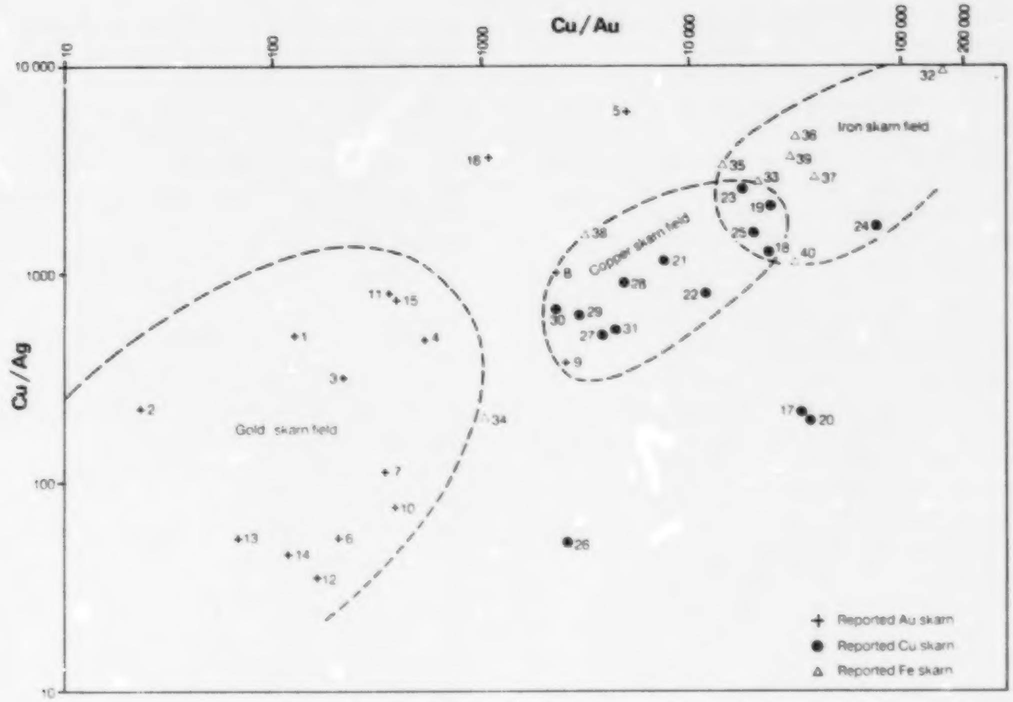

Figure 50. Plot showing Cu/Ag versus Cu/Au ratios of the 40 deposits listed in Tables 6, 7, and 8, which are described by various authors as "gold", "copper" or "iron" skarns. Note the contrasting fields outlining the three skarn types.

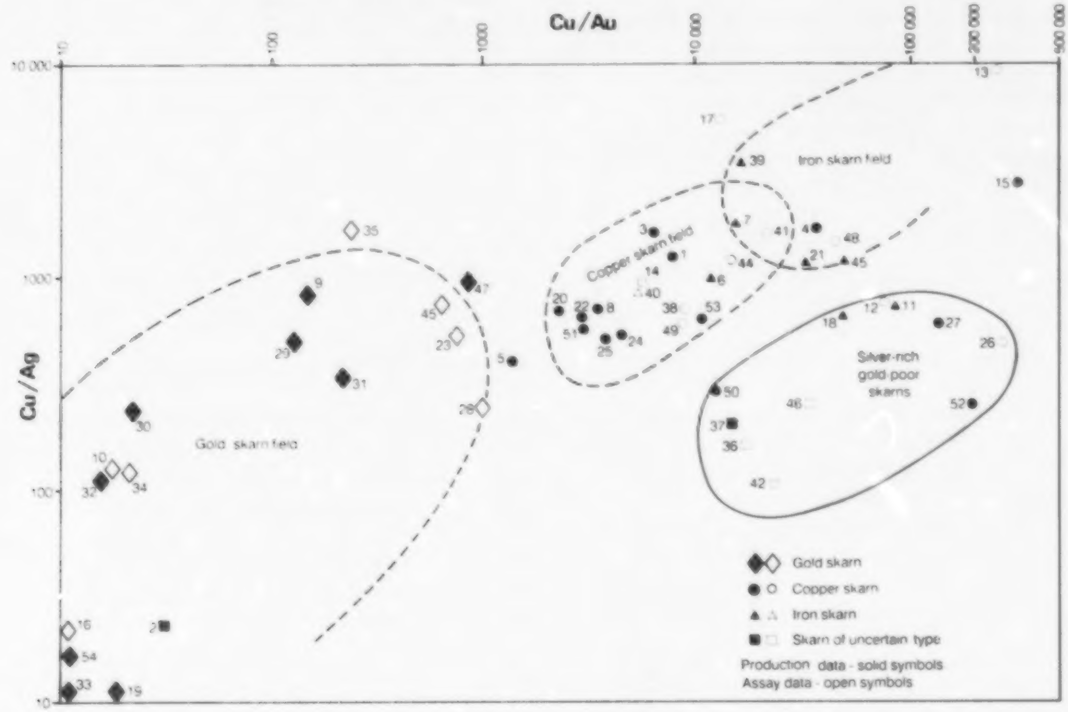

Figure 51. Plot showing Cu/Ag versus Cu/Au ratios of the 54 PME skarns in British Columbia listed in Table 9. Note that four fields are differentiated, and that the deposits in the silver-rich, gold-poor field often has lead-zinc skarn affinities.

TABLE 9
Cu/Au AND Cu/Ag RATIOS OF SOME PME SKARNS IN BRITISH COLUMBIA

NO. IN FIG. 51	NAME	Cu/Au	Cu/Ag	DATA SOURCE*
1	Phoenix	8182	1267	P
2	Marshall	31	26	P
3	Motherlode (Sunset)	6476	1631	P
4	Greyhound	37312	1710	P
5	Morrison	1337	411	P
6	Emma (Bluebell)	11084	965	P
7	Oro Denoro	14452	1772	P
8	Loyal Canadian	3429	700	P
9	Dividend-Lakeview	145	829	P
10	Heino-Money Zone	17	125	A
11	Orinoco	87962	708	P
12	Elk	77352	744	A
13	Trio	2633333	9294	A
14	Liquid Sunshine	5500	951	A
15	Blue Grouse	31261467	2716	P
16	Beano (Bingo)	10	24	P
17	Geo (Star of the West)	12360	5591	A
18	Dewdney	49071	645	P
19	Silverado	16	9	P
20	Little Billie	2256	663	P
21	Texada Iron	30112	1130	P
22	Cornell	2906	623	P
23	Security (Florence)	739	543	A
24	Marble Bay	4397	537	P
25	Copper Queen	3851	509	P
26	King Midas	286666	502	A
27	Cambrian Chieftain	139666	592	P
28	Jane-Toni	1000	243	A
29	Hedley Mascot	125	510	P
30	Nickel Plate (underground)	23	235	P
31	Nickel Plate (open pit)	222	333	A
32	French	15	113	P
33	Good Hope	4	5	P
34	Canty	22	122	A
35	Peggy	248	1733	A
36	Sunset	16000	158	A
37	Lucky Mike	14129	205	P
38	Nat No. 4	8965	724	A
39	Old Sport	10646	3511	P
40	Merry Widow	5375	860	A
41	Tarn (Miller)	20333	1554	A
42	Park	23363	105	A
43	Fire (Kaza)	628	765	A
44	Moult	13333	1290	A
45	Tasu	44676	1187	P
46	Ajax (Garnet)	33333	258	A
47	Morning (Lotus)	828	965	P
48	Edd (Great West)	43870	1462	A
49	Quartz Hill	8398	631	A
50	Gribble Island	12000	284	P
51	Molly B	3033	595	P
52	Maid of Erin	109029	253	P
53	Lilly	11214	665	P
54	Second Relief	6	23	P

*P = production data, Appendix 1; A = assorted assay values.

listed in Table 9, represent those skarns for which gold, silver and copper values are available. In 33 of them the Cu:Au and Cu:Ag ratios were determined from production data, while metal ratios in the remaining 21 skarns were calculated using drill-core or grab-sample assays.

Most of the deposits and occurrences believed to represent either gold, copper or iron skarns in Table 9 fall within their appropriate fields in Figure 51. Notable exceptions occur in a small number of copper skarns that are barren in gold which results in a high Cu:Au ratio more characteristic of iron skarns. Blue Grouse (No. 15), Greyhound (No. 4) and Trio (No. 13) are examples of this. One interesting feature illustrated by Figure 51 is the recognition of a fourth skarn field characterized by its high silver and low gold content. This field may have lead-zinc skarn affinities since many of its deposits are relatively enriched in lead and:or zinc. These deposits include the Orinoco (No. 11), Cambrian Chief (No. 27), Sunset (No. 36), Lucky Mike (No. 37) and Park (No. 42). It should be noted that in Figure 50, the skarns of the Clifton district (No. 17) and the Moncocco skarn (No. 20) lie within this silver-enriched, gold-poor field.

It is interesting to compare pie charts of the gold and silver production (Figure 52) from the four types of PME skarns outlined in Figures 50 and 51. As expected, the largest contribution (53 per cent) to the total skarn-derived gold production in British Columbia has been won from the gold skarns. However, copper and iron skarns respectively account for approximately 40 per cent and 7 per cent of the gold, while the fourth group, that commonly possesses lead-zinc affinities, is responsible for only 0.2 per cent of the total gold production.

The amount of silver production from the four skarn types outlined in Figure 51 is shown in Figure 52B. This illustrates that the gold skarns account for the least silver production, a mere 1.8 per cent. By contrast the copper (dominated by the Phoenix mine) and iron skarns are responsible for over 95 per cent of the skarn-derived silver production in British Columbia, while only 2.5 per cent is derived from the fourth, silver-rich type with lead-zinc affinitites.

To summarize, for a variety of reasons, PME skarns cannot be adequately classified using many of the criteria satisfactorily employed to classify and define base and ferrous metal skarns. Metal ratio plots, particularly Cu:Ag versus Cu:Au ratios, broadly outline gold, copper and iron skarns as well as a group of silver-enriched, gold-poor skarns that commonly have lead-zinc enrichment. However, Cu:Ag versus Cu:Au ratio plots are unfortunately unsuitable for classifying any group of PME skarns which is impoverished in copper, but enriched in either lead, zinc, tungsten or molybdenum. This group would include the copper-poor PME skarns at Tillicum Mountain.

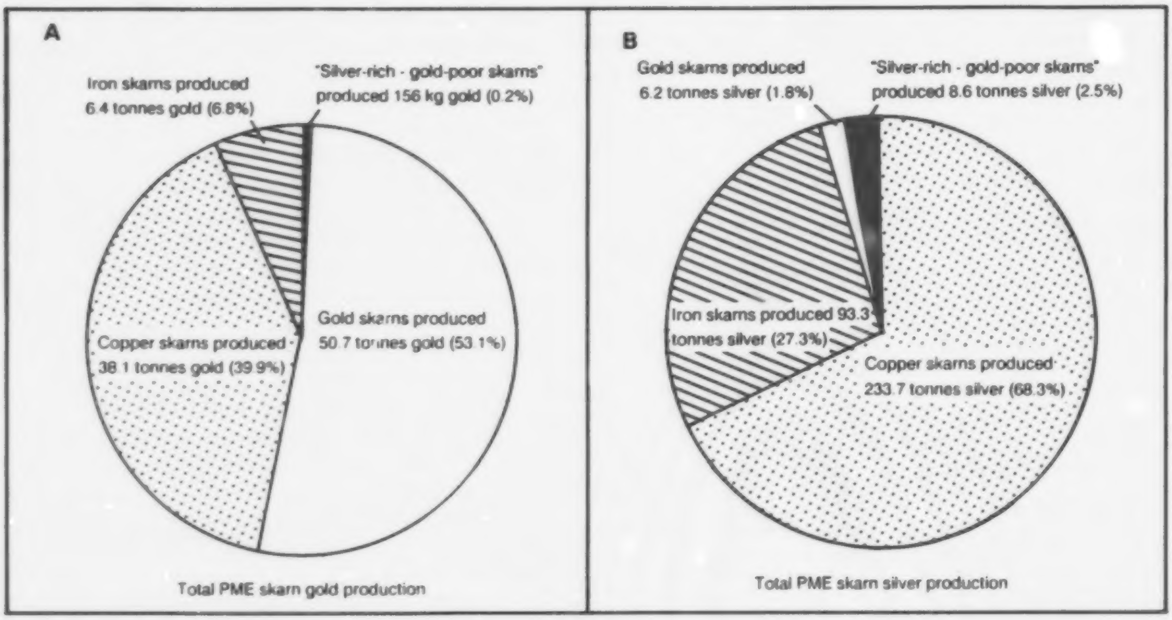

Figure 52. Relative production of gold (A) and silver (B) in British Columbia from each of the four different types of PME skarns outlined in Figure 51.

CHAPTER 8

SUMMARY

Historically, skarn deposits throughout the world have been an important source of iron, copper, molybdenum, lead, zinc, tin and tungsten. However, some skarns also contain economically recoverable amounts of gold, silver and more rarely, platinum, and the importance of this class of skarn deposit as a primary source of precious metals has only recently been widely recognized. All mineralized skarns contain some precious metals ranging from parts per billion levels up to economic quantities. In the latter case the precious metals may be the primary commodity recovered but most gold and silver produced from skarns worldwide have probably been derived as byproducts of base or ferrous metal mining.

Although base and ferrous metal skarns are developed in a wide variety of geological environments, tectonic regimes and hostrock lithologies (Zharikov, 1970; Einaudi *et al.*, 1981; Kwak, 1987), PME skarns tend to be far more restricted, being generally confined to relatively young, Phanerozoic mobile belts characterized by oceanic island arc and back-arc basin assemblages and arc-related plutonism.

British Columbia contains numerous iron, copper, molybdenum, lead, zinc, tin and tungsten skarns, and a total of approximately 350 skarn deposits and occurrences are recorded in the British Columbia Geological Survey Branch MINFILE database. Of these, at least 126 skarns report anomalous values of gold, silver or (very rarely) platinum. From these 126 PME skarns, 49 individual skarn deposits have produced a total of 95 tonnes of gold and 342 tonnes of silver. Over 53 per cent of the gold was won as a primary commodity, and the remaining 47 per cent of the gold and virtually all of the silver was recovered as a byproduct, largely from copper or iron mining. Skarn-related precious metal production has been dominated by two world-class mines, the Nickel Plate deposit (Hedley camp) and the Phoenix deposit (Greenwood camp) which together account for 82 per cent of the gold and 57 per cent of the silver recovered from skarn deposits in British Columbia.

The following conclusions are made regarding PME skarns in British Columbia:

(1) The overwhelming majority of PME-skarn occurrences and producers are calcic skarns. PME magnesian skarns are exceedingly rare in British Columbia. The only PME magnesian skarn mined (Salmo-Malarctic) produced some silver but no gold.

(2) Most of the PME skarns in the province are hosted by deformed oceanic island arc and back-arc basin sequences that range from Cambrian to Cretaceous in age. However, there is an apparent temporal control on the distribution of PME-skarn producers in British Columbia; more than 60 per cent are hosted in Triassic rocks and 43 per cent are associated with Jurassic intrusions. This is because most of the extensive arc assemblages favourable to PME skarn development are Late Triassic in age and are intruded by Early to Middle Jurassic, arc-related plutons. Favourable arc assemblages in British Columbia include the Nicola, Takla, Stuhini, Lewes River, Vancouver, Sicker and Rossland groups. Other Late Triassic subduction-related assemblages occurring further south in the United States include rocks of the Wallowa, Old Ferry, Rattlesnake Creek, Jackson and Foothills terranes which are also thought to have good potential for PME skarns.

(3) PME-skarn occurrences are distributed throughout the Insular, Coast, Intermontane and Omineca tectonic belts, but there are no known occurrences within the easternmost Foreland Belt. Although 76 per cent of the PME skarns which have been mined are concentrated within the Insular and Omineca belts, over half of the gold produced (53 per cent) has originated from the Intermontane Belt, reflecting the Hedley camp production. By contrast 98 per cent of the silver has come from the Insular and Omineca belts.

(4) PME skarns occur within 14 different tectonic terranes as defined by Wheeler *et al.* (1988). However, 78 per cent of the occurrences are confined to just four of these terranes, namely Wrangellia, Quesnellia, Stikinia and Alexander. Two of these (Wrangellia and Quesnellia) account for 86 per cent of the producing mines, while the remaining two (Stikinia and Alexander) contain a mere 4 per cent of the producers. This discrepancy may reflect poorer access and less exploration in the Stikinia and Alexander terranes which may therefore have good PME-skarn potential.

(5) Over 80 per cent of the PME-skarn occurrences are associated with deformed limestone or marble-rich sequences that often also contain some shale/argillite, tuff and volcanic flow components. Some favourable arc sequences, such as the Nicola and Rossland groups, include potassium-rich volcanic shoshonites and limestone-boulder conglomerates or olistrostromes.

(6) The intrusive rocks associated with PME-skarn mineralization range compositionally from granite to gabbro although quartz diorite and diorite are the most common. The intrusions form stocks of variable size, as well as sills and dikes; they may include rocks of several different compositions within the same district. This is often manifest as early, small bodies of more mafic, skarn-related intrusives, followed closely in time by larger volumes of generally barren, more felsic material that forms major batholiths. It is likely that these two phases are related to a single plutonic event.

(7) Many of the intrusions related to PME-skarns in British Columbia are porphyritic with phenocrysts of hornblende and/or zoned plagioclase.

(8) All of the PME-skarn-related intrusions analysed in the province to date are subalkalic and I-type, and overwhelmingly calc-alkaline in composition. Although no gold skarns associated with alkalic rocks have yet been positively identified in British Columbia, some alkalic, high-level intrusions in the Nicola Group are associated with gold-bearing porphyry copper deposits such as Copper Mountain (Fahrni *et al.*, 1976) and Cariboo Bell (Hodgson *et al.*, 1976) that locally contain garnet-pyroxene-epidote-scapolite skarn-like alteration features.

(9) The calc-silicate mineral assemblages associated with PME skarns are similar to those found in end-member ferrous and base metal skarns and thus cannot usually be used to distinguish skarns with precious metal potential. However, PME skarns tend to be rich in pyroxene relative to garnet.

(10) Most of the gold skarns in the Hedley district are characterized by the presence of scapolite. In the Nickel Plate deposit scapolite was coeval with the main gold-sulphide event and is spatially associated with the orebodies close to the base of the skarn envelope. Scapolite is not widely reported in other PME-skarns in British Columbia, possibly because it is not easily identified. Its presence may be indicative of a skarns gold potential.

(11) Most PME skarns in the province are characterized by low manganese (<0.5 weight % MnO) grandite garnets which probably reflects the close relationship between many PME skarns and iron and copper skarns which also have grandite garnets and tend to occur within similar island arc and back-arc basin environments. The notable exceptions are the PME skarns in the Tillicum Mountain camp, where the garnets are manganese rich. Although these skarns are hosted in presumed back-arc basin rocks of the Early Jurassic Rossland Group, the unusual garnet composition may result from the influence of more continental-type basement rocks at depth.

(12) The garnets, and to a lesser extent the pyroxenes, associated with PME skarns, may vary in composition either throughout a deposit or across individual crystals. Electron microprobe data suggest that some andraditic garnet crystals in PME skarns contain narrow, aluminum-rich growth zones, while other garnets show a progressive increase in their aluminum (grossular) contents from core to rim. This contrasts with ferrous and base metal skarns in which the garnets reportedly become progressively andraditic in composition towards the crystal margins.

(13) Some pyroxenes in PME skarns are sporadically enriched in alumina compared to pyroxenes in base and ferrous metal skarns. Like the garnets, this enrichment is confined to narrow growth zones in the volumetrically more abundant alumina-poor pyroxene crystals. It is possible that these aluminous zones are physiochemical signatures related to the gold precipitation. Thus alumina enrichment in skarn pyroxenes may indicate precious metal potential. Preliminary data on pyroxenes suggest that, depending on their FeO content, some Al_2O_3 + TiO_2 values exceeding 1.25 weight per cent in the pyroxenes indicate the deposit has good PME-skarn potential. Nevertheless, in some PME-skarns, such as the Nickel Plate deposit, the pyroxenes have low Al_2O_3 + TiO_2 contents similar to those in ferrous and base metal skarns. Therefore low-alumina pyroxenes do not necessarily rule out the gold potential of a deposit. However, skarns with pyroxenes containing either less than 3.5 per cent or greater than 26 per cent FeO are believed to have a very low precious metal potential.

(14) Gold and silver mineralization are usually associated with sulphides and other opaque minerals that were generally deposited after the prograde silicate skarn assemblages. Pyrrhotite, pyrite, chalcopyrite, arsenopyrite, bornite, sphalerite and cobaltite are the most common sulphides in PME skarns having iron and copper skarn affinities. These minerals preferentially replace the carbonate-rich protolith units and may be sporadically associated with magnetite, or more rarely with scheelite and molybdenum. PME skarns having gold as the primary commodity are commonly characterized by arsenopyrite, hedleyite, bismuthinite, native bismuth, maldonite and cobaltite, which may be intimately associated with the gold mineralization. Very little data are yet available

regarding the gold content of the individual sulphide phases in PME skarns. However, one Russion study (Vakhrushev and Tsimbalist, 1967) suggests that the gold content of pyrite can be used to evaluate the precious metal potential of a skarn deposit.

(15) Some PME-skarn envelopes exhibit mineralogical zoning patterns in their prograde, exoskarn silicate mineral phases. Recognition of these zones, manifest as garnet-dominant proximal zones and pyroxene-rich distal zones, may assist in exploration. In some instances the outermost margins of the smaller skarn envelopes are marked by biotite hornfels zones which predate the garnet and pyroxene phases and which developed during the early stages of the skarning process. The later sulphide-rich precious metal mineralization is rarely developed in the endoskarn, but is generally hosted by the pyroxene-dominant exoskarn in the outer parts of the pyroxene skarn envelope.

(16) At some PME-skarn camps, such as Hedley and Texada Island, there are indications that the skarn deposits exhibit progressive changes in metallogeny across the districts. These district-wide variations may include changes from iron to copper-gold skarns, copper to gold skarns or tungsten-copper to gold skarns and may also be accompanied by zoning patterns in other associated trace elements.

(17) There is a highly variable trace element association with gold in PME-skarns which may be enriched in one or more of the following: Au, Ag, Te, Cu, As, Co, Bi, Zn, Fe and W. Local enrichment of Pb, Ni, Mo, Sb, Sn and Pt may also occur. The PME skarns in some camps such as Hedley are enriched with many of these trace elements, while other gold-enriched skarns contain only a few of these elements. Four separate groups of elemental associations are identified, based on linear correlation coefficients and observed mineral assemblages. The strongest correlations occur among the silver-lead-zinc group. The copper-zinc association results from the close relationship between chalcopyrite and sphalerite. As no significant amounts of native silver or silver minerals have been identified in PME skarns, the strong correlation with silver is probably due to solid solution silver occurring within the chalcopyrite and/or sphalerite.

(18) The presence of lead, nickel and more commonly, bismuth tellurides appears to be a characteristic of many end-member gold skarns which suggests that anomalous tellurium and bismuth are good geochemical indicators of a skarn's gold potential. Native bismuth, bismuthinite, hedleyite and maldonite are persistent mineral phases associated with the gold mineralization, and in this study gold is the only element which exhibits a significant positive correlation with bismuth in PME-skarns (no samples were analysed for tellurium). Because bismuth is more mobile than gold in slightly acidic solutions at surface temperatures, it may represent one useful pathfinder element for soil geochemistry surveys exploring for PME skarns.

(19) The degree of retrograde alteration (chlorite, epidote, tremolite-actinolite) overprinting the prograde garnet-pyroxene assemblages varies enormously from deposit to deposit and cannot be used to indicate PME-skarn potential. The Nickel Plate deposit and most of the other PME skarns in the Hedley district exhibit very little retrogression, while others such as the Dividend-Lakeview gold skarn show marked retrograde alteration. Generally, retrogression appears to be more common and severe in the PME-iron skarns.

(20) Gold in PME skarns varies from very coarse grained, free and visible (for example, the Heino-Money zone, Tillicum Mountain camp) to micron-sized particles intimately associated with sulphides, as present at the Nickel Plate mine.

(21) PME skarns cannot be adequately classified using the criteria employed to classify ferrous and base metal skarns. However, metal ratio plots, particularly Cu:Ag versus Cu:Au ratios, can broadly outline and differentiate gold, copper and iron skarns, as well as a group of silver-enriched, gold-poor skarns that commonly have lead-zinc skarn affinities. Gold skarns tend to have Cu:Au ratios less than 1000, copper skarns between 2000 and 25000, while iron skarns have Cu:Au ratios between 20 000 and 160 000.

(22) Comparative whole-rock geochemistry in the Hedley district suggests that the altered diorite sills (endoskarn) gained sodium, potassium and silica but underwent a considerable loss of total iron during the skarn process. The adjacent calcareous siltstones (exoskarn), gained considerable iron, aluminum, silica and potassium, and lost calcium and carbon dioxide.

(23) The amount of skarn alteration associated with precious metal mineralization varies considerably, from narrow alteration envelopes of less than 10 metres up to those exceeding several hundred metres in width as developed in the Hedley camp. The volume of skarn alteration appears to be proportional to the amount of gold in the system. Thus, large tonnage precious metal deposits are more likely to be found in areas containing larger skarn alteration envelopes.

(24) Fault-controlled, island arc or back-arc-related marine basin margins have excellent exploration potential for PME skarns because:

(a) They often contain volcaniclastic and sedimentary lithologies (calcareous sediments, limestone-boulder conglomerates) suitable for skarn development.

(b) The deep basement structures localize the late, arc-related plutonic activity favourable for PME skarn development.

(25) To summarize, the most favourable areas for PME-skarn exploration in British Columbia are:

(a) Within the Quesnellia, Wrangellia, Alexander and Stikinia terranes.

(b) Adjacent to fracture-controlled, island arc or back-arc basin margins containing Late Triassic to Early Jurassic limy clastic supracrustal rocks and a varied suite of arc-related, subalkalic, calc-alkaline I-type intrusions of Jurassic-Cretaceous age.

Areas with iron, copper, tungsten, lead or zinc skarns, porphyry copper mineralization or arsenic, bismuth, tellurium or cobalt geochemical enrichment are particularly attractive. However, it is emphasized that all skarns of any type should be routinely checked for precious metal enrichment. Regions with these favourable criteria include areas underlain by the Nicola, Rossland, Vancouver and Sicker groups in southern British Columbia and the Takla, Stuhini and Lewes River groups further north. It is believed that British Columbia offers excellent potential for the discovery of new economic PME-skarn deposits similar to those mined in the Hedley and Greenwood camps.

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ADDENDUM - SOME OTHER PME SKARNS IN BRITISH COLUMBIA

While this paper was being concluded, several additional PME skarns or possible skarns came to our attention. Of these, the most important is the Second Relief mine, near Nelson, which has been a major gold producer. The others are either small occurrences or prospects that are currently being explored. We were unable to include details of these PME skarns in Appendix 1, but they are described briefly below.

SECOND RELIEF MINE
(MINFILE 082FSW187)

The Second Relief mine is situated on the east side of Erie Creek, approximately 20 kilometres south-southwest of Nelson. The mine was worked from 1900 until 1948, with most production occurring after 1933. MINFILE reports that a total of 206 632 tonnes of ore was milled which yielded 3.11 tonnes of gold, 0.86 tonne of silver, 20.2 tonnes of copper, 1 tonne of lead and 324 kilograms of zinc. Mineralization is associated with several parallel northeast-striking, steeply dipping veins which reach up to 4 metres in width and comprise mainly quartz with minor magnetite, garnet and epidote. Recent work (Höy and Andrew, 1989) indicates the mineralized veins are also associated with widespread wallrock skarn-alteration. Production data indicate the ore graded 15 grams gold per tonne and that the mineralization has Cu:Au and Cu:Ag ratios of 6 and 23, respectively (Table 9). These ratios place the deposit within the gold-skarn field in Figure 51.

The Second Relief deposit is hosted by Lower Jurassic shoshonitic, augite porphyry basalts and tuffs of the upper Elise Formation (Rossland Group), close to its faulted contact with the older Archibald Formation and the intrusive margin of the Nelson batholith (Höy and Andrew, 1989). Mineralization follows the hangingwall contact of a diorite porphyry dike. The main economic vein contains pyrite, pyrrhotite and chalcopyrite with traces of molybdenite and gold.

Skarn alteration overprints both the volcanics and the feldspar porphyry diorite; it is commonly highly siliceous and contains euhedral brown-coloured garnet, epidote, amphibole, clinopyroxene, carbonate, minor biotite, and trace tourmaline. This calc silicate assemblage is cut by later quartz veins and masses of coarse pyrite, pyrrhotite and minor chalcopyrite.

The mineralization is geochemically anomalous in arsenic and bismuth (M.E. Caron, personal communication, 1989) but it is not known whether tellurides are present.

The garnets are massive and anhedral; microprobe analyses (by G.E. Ray at The University of British Columbia) indicate they are iron rich, ranging in composition from 74 to 80 mole per cent andradite and from 4 to 11 mole per cent pyralspite. The garnets are isotropic and show little compositional zoning.

The presence of both the Tillicum Mountain camp and Second Relief deposit in the Rossland Group emphasizes the excellent potential of these rocks for further PME-skarn exploration.

SYLVESTOR K
(MINFILE 082ESE031)

The Sylvester K claims in the Greenwood camp lie close to the Marshall skarn deposit, approximately 1.7 kilometres northwest of the Phoenix mine. The geology of the Sylvester K has been described by Church (1984, 1986). Triassic Brooklyn Formation rocks comprising sharpstone conglomerate, argillite, tuff and minor limestone underlie the area. These are intruded by the Providence Lake microdiorite, which has been dated at 206±8 Ma by K:Ar analysis (Church, 1986). Mineralization forms a steeply dipping zone of massive sulphides that locally reaches 6 metres in thickness and is traceable intermittently over a total length of 245 metres. Drilling by Kettle River Resources Ltd. delineated approximately 50 000 tonnes of mostly low-value pyritic mineralization, although isolated samples exceed 10 grams gold per tonne (Church, 1986). The mineralization consists principally of pyrite with lesser amounts of pyrrhotite and marcasite, and trace quantities of chalcopyrite accompanied by carbonate, quartz and chlorite. Locally, the footwall argillites adjacent to the sulphide zone are altered to a fine-grained biotite hornfels which is cut by thin pyrite stringers enriched in gold and silver (Church, 1986).

Approximately 400 metres north of the Sylvestor K, and in a similar structural setting, is the San Jacinto sulphide zone which includes pyrite with pyrrhotite, magnetite, specularite, galena, garnet, epidote and amphibole.

The precise origin of the Sylvestor K mineralization is controversial. Church (1986) and K. Dawson of the Geological Survey of Canada (quoted in Church, 1984) believe it represents a sulphide-rich skarn related to the Providence Lake microdiorite. However, geologists with Kettle River Resources Ltd. have suggested the mineralization represents massive sulphides formed by syngenetic exhalative processes, similar to the "stratiform skarn" deposits described by Stanton (1987). It is noteworthy that andradite garnet with well-crystallized pyroxene and amphibole has been found as an authigenic product in some of the recent Red Sea metal-bearing sediments (Zierenberg and Shanks, 1983, quoted by Stanton, 1987).

HUMMINGBIRD
(MINFILE 104G050)

Continental Gold Corporationt has been exploring the Hummingbird PME-skarn occurrence and several other gold discoveries which are situated within the Stikine River basin, approximately 80 kilometres south of Telegraph Creek. Mineralization is hosted by Permian limestones close to their stratigraphic contact with mid-Triassic siltstones (Logan and Koyanagi, 1989). The nearby monzonitic Hickman pluton of mid-Triassic age is thought to be responsible for the skarn mineralization. Alteration assemblages include garnet, carbonate, pyroxene, quartz and chlorite. Opaque minerals include pyrite, pyrrhotite, chalcopyrite and magnetite. Other structurally controlled mineralized zones elsewhere in the area contain sphalerite, galena, arsenopyrite, native gold and electrum (George Cross Newsletter, No. 224, November 22, 1988). The weighted average of assays from four chip samples gave 0.69 gram gold and 10.28 grams silver per tonne and 0.6 per cent copper.

STEEP PROPERTY

This property is located on the west side of Adams Lake, approximately 55 kilometres northeast of Kamloops. The regional geology is described by Okulitch (1979), and by Schiarizza and Preto (1984; 1987). The mineralization is hosted by northeast-dipping argillaceous limestones and black calcareous phyllites of the Sicamous Formation, close to their contact with the structurally overlying Eagle Bay assemblage. The Sicamous Formation was assigned a Late Triassic age by Okulitch (1979), but is now thought to be of Paleozoic age (Okulitch, 1985). It is inferred to be a facies equivalent of part of the Early Cambrian to Mississippian Eagle Bay assemblage (Schiarizza and Preto, 1984, 1987). Eagle Bay rocks, which sit structurally above the Sicamous Formation in the vicinity of the Steep property, comprise Devonian felsic metavolcanics and associated metasediments together with Devonian orthogneiss presumed to be comagmatic with the metavolcanics. Quartz porphyry schists which occur locally within the skarn-altered Sicamous Formation are thought by Schiarizza and Preto (1987) to be feeder sills related to the overlying metavolcanic rocks.

Recent exploration work on the property, including some diamond drilling, has been conducted by National Resources Explorations Limited, and a summary of the skarn mineralization and geochemistry has been presented by Miller (1988), and Miller *et al.* (1988). A concordant zone of skarn alteration that reaches several hundred metres in width is traceable for at least 10 kilometres along strike. It includes calc-silicate and garnet-rich skarn; the former is up to 80 metres thick, and mainly comprises fine grained amphibole, plagioclase, and epidote with lesser amounts of biotite, sphene, chlorite, apatite, plagioclase and potassium feldspar. Minor amounts of pyroxene have been identified in thin section although it is mainly altered to chlorite and epidote (D.Miller, personal communication, 1989).

Pyrrhotite average 5 per cent and is the dominant sulphide. Layers of massive pyrrhotite and minor magnetite occur together locally. Other sulphides include pyrite, chalcopyrite and rare sphalerite and galena which may form fine intergrowths with the pyrrhotite. Miller *et al.* (1988) report that the gold forms minute grains, 5 to 15 microns in diameter, which generally occurs with the pyrrhotite. The gold is also associated with minute grains of native bismuth and bismuth tellurides. Mineralization tends to be found close to the outer margin of the skarn zone.

Soil sampling suggests that the areas of higher gold values coincide with anomalous values of arsenic and copper, and to a lesser extent with lead and zinc. The best drillhole intersection recorded 3 metres of 5.8 grams per tonne gold. However maximum assay values for other elements were 22 grams per tonne silver, 2000 ppm arsenic, 272 ppm bismuth, 3830 ppm copper, 6910 ppm lead, 1.5 per cent zinc and 173 ppm antimony (Miller *et al.*, 1988). A visual examination of the assay results suggests that gold has a relatively poor correlation with silver, arsenic, antimony and lead but a strong positive correlation with bismuth. Copper, lead, zinc, arsenic and antimony all exhibit a good positive correlation with each other.

The age and origin of the Steep property mineralization is unknown, and it is uncertain whether it represents an intrusion-related, epigenitic skarn, or a syngenetic, exhalitive "stratiform skarn" deposit similar to those proposed by Stanton (1987).

APPENDICES

APPENDIX 1. COMPILED DATA CONCERNING 126 PME – SKARN OCCURRENCES IN BRITISH COLUMBIA

Loc. No. in Fig. 3	Name(s)	NTS MINFILE	Type*	Production (ore t)	Associated Intrusive Rocks	Host Rocks	Skarn Mineralogy	Opaque Mineralogy	Associated Metallic Elements	Comments	References
1	Oka (Greata)	82E/13W 082ENW025	O		Mesozoic granodiorite-diorite	Late Triassic Nicola Group – limestone, argillite, siltstone, volcaniclastics	gt-pyx-ep-wo-tr-qtz-cc-bio	py-po-as-cp-sl	Au-As-Cu-Ag-Zn	Au occurs in sulphide pods along skarn – marble contacts and in faults cutting skarn.	AR 15834, 7872; GEM 1979 - 46; Ettlinger and Ray (1988)
2	Phoenix mine (Brooklyn, War Eagle, Old Ironsides, Snowshoe and associated claims)	82E/2E 082ESE013, 082ESE014, 082ESE015, 082ESE016-028, 030	P	(26 956 525 t) Au - 30 225 kg Ag - 192 055 kg Cu - 230 050 t Pb - 1 t	Uncertain – Cretaceous Nelson granodiorite is primary intrusive phase in district	Triassic Brooklyn Group – sharpstone conglomerate, limestone, argillite, tuff	gt-ep-chl-cc-amph-qtz	cp-py-hm-mt	Au-Ag-Cu-Pb	Includes numerous underground and surface mines to form Phoenix pit and satellite deposits. Skarn replaces bedding in conglomerate and limestone but is cut by numerous faults which may have acted to channel fluids.	Church (1986); Peatfield (1978); Little (1983)
2	Marshall (Brandon, San Jacinto)	82E/2E 082ESE031	P	(194 t) Au - 15 kg Ag - 18 kg Cu - 472 kg Pb - 2 318 kg Zn - 555 kg	Late Triassic microdiorite 206 ± 8 Ma (K/Ar)	Triassic Brooklyn Group – sharpstone conglom., argillite, siltstone, limestone	gt-ep-amph-pyx-chl	py-po-mc-cp-mt-hm-gl-sl	Au-Ag-Cu-Pb-Zn	Sulphides occur as small pods and disseminated at siltstone – limestone contacts.	EMPR–MINFILE
2	Motherlode (Sunset)	82E/2E 082ESE034	P	(4 245 875 t) Au - 5 391 kg Ag - 21 406 kg Cu - 34 915 t	Late Jurassic Wallace Creek granodiorite	Triassic Brooklyn Group – limestone, sharpstone conglomerate	gt-act-ep-cc-qtz-tr-chl	cp-py-mt-hm	Au-Ag-Cu	At Motherlode the orebody is flanked by limestone and a steep-dipping normal fault; at the adjacent Sunset mine, the ore zones are flat lying in limestone. Both are underlain by thrust faults.	Church (1986); Peatfield (1978)
2	Greyhound (Ah There)	82E/2E 082ESE049 082ESE050	P	(221 200 t) Au - 16 kg Ag - 349 kg Cu - 597 000 kg	Cretaceous Greenwood granodiorite	Triassic Brooklyn Group – limestone	gt-ep-chl-act-cc	py-cp-po-mt-hm	Au-Ag-Cu	Skarn is highly brecciated. Sulphides occur along limestone-endoskarn contact.	Church (1986)
2	Morrison	82E/2E 082ESE052	P	(2 647 t) Au - 8 kg Ag - 26 kg Cu - 10 700 kg	Late Jurassic Wallace Creek granodiorite. 150±5 Ma (K-Ar)	Triassic Brooklyn Group – limestone; Paleozoic Knob Hill Group – metacherts and schists	NR	py-po-cp	Au-Ag-Cu		Church (1986)
2	Emma (Bluebell)	82E/2E 082ESE062	P	(240 948 t) Au - 212 kg Ag - 2 434 kg Cu - 2 350 t	Late Jurassic Wallace Creek granodiorite. 150±5 Ma (K-Ar)	Triassic Brooklyn Group – limestone	gt-ep-pyx-cc-qtz-sc-zo-cz	mt-cp-py-po-hm-tt	Au-Ag-Cu-Sb	Orebody is vertical, subparallel to bedding in ls. and follows the eastern contact of granodiorite.	Church (1986); Peatfield (1978)
2	Oro Denoro	82E/2E 082ESE063 082ESE064	P	(124 001 t) Au - 117 kg Ag - 954 kg Cu - 1 691 t	Late Jurassic Wallace Creek granodiorite. 150±5 Ma (K-Ar)	Triassic Brooklyn Group – limestone, sharpstone conglomerate	gt-pyx-qtz-cc-chl-ep	mt-hm-cp-py-po-tt	Au-Ag-Cu-Sb-Zn	Skarn is controlled by fractures perpendicular to bedding in limestone. Endoskarn in granodiorite is common.	Church (1986); Peatfield (1978); GEM 1974 - 38

* O = Occurrence or prospect
P = Producing mine or past producer

(Appendix 1 continued)

Loc. No. In Fig. 3	Name(s)	NTS MINFILE	Type	Production (ore t)	Associated Intrusive Rocks	Host Rocks	Skarn Mineralogy	Opaque Mineralogy	Associated Metallic Elements	Comments	References
2	Rockland (Stan)	82E/2E 082ESE132	O		Cretaceous Nelson granodiorite	Paleozoic Attwood and Knob Hill Groups – quartzite., arg., ls., greenstone	gt-amph-ep-cc-qtz	mt-hm-py-cp-bn-chc-moly	Au-Cu-Zn-Mo	Skarn in embayments in igneous rock. Sulphides as irregular pods and disseminations in skarn.	GEM 1972 - 36
2	Fanny Joe	82E/2E 082ESE159	O		Cretaceous Nelson diorite	Permo-Carbon. Attwood Group – black shale, greywacke, limestone	NR	py-cp-sl-gl-mt-po-as	Au-Ag-Cu-Pb-Zn-As	Au occurs in silicified and sheared Attwood sediments.	GEM 1976 - E20; AR 5872
2	Sunnyside (Bev, TW)	82E/2E 082ESE160	P	(45 t) Au - 373 g Ag - 81 645 g Pb - 4 340 kg Zn - 420 kg	Cretaceous Nelson diorite	Permo-Carbon. Attwood Group – black shale, greywacke, limestone	NR	cp-po-as	Au-Ag-Cu-Pb-Zn-As	Au occurs in silicified and sheared Attwood sediments near granodiorite contacts.	GEM 1976 - E20; AR 5872
3	Schickshock (Sailor Boy)	82E/1W 082ESE077	O		Cretaceous Nelson diorite. Tertiary intrusions?	Triassic Brooklyn Group – arg., ls., sharpstone conglomerate	gt-cc	mt-po-py-cp-sl	Au-Ag-Cu-Zn-Pb	Host is fine-grained, foliated light brown garnet skarn.	Peatfield (1978); AR 5057
3	Loyal Canadian (Seattle)	82E/1W 082ESE158	P	(296 t) Au - 902 g Ag - 4 416 g Cu - 3 093 kg	Cretaceous Nelson granodiorite – diorite dykes	Limestone, limy grit	NR	cp-chc-py-mt-mal-sl	Au-Ag-Cu-Zn		GEM 1969 - 309; AR 4424, 3780
4	Dividend – Lakeview	82E/4E 082ESW001	P	(111 250 t) Au - 504 kg Ag - 88 kg Cu - 73 t Pb - 71 kg Zn - 71 kg	Cretaceous (?) Osoyoos batholith, granodiorite-quartz diorite	Triassic Kobau Group or Paleozoic Anarchist Group – quartzite, schist, limestone, greenstone	gt-ep-amph-pyx-wo-chl-qtz-cc	po-py-mc-as-cp-mt-hd	Au-Ag-Cu-Pb-Zn-Co-As-Bi-Te	Skarn formation follows bedding along metavolcanic-marble contact. Cl-rich ferrohastingsite and actinolite occur with gold-bearing sulphides replacing garnet skarn.	AR 11924; 9180; Cockfield (1935); McKechnie (1964); Ettlinger and Ray (1988)
5	Juniper (Bell)	82E/4W 082ESW170	O		Late Mesozoic Olalla stock – syenodiorite to pyroxenite	Paleozoic – Triassic (?) Shoemaker Formation – quartzite and argillite. Apex Mountain Group – ophiolite sequence	gt-pyx-ep-chl	py-po in skarn cp-tt-mal-az in crosscutting quartz veins and shears	Au-Ag-Cu	Skarn assayed: 0.07 - 6.0 g/t Au; 1.0 - 5.8 g/t Ag; Vein assayed: 6.8 - 11.1 g/t Au; 6.8 - 589.7 g/t Ag. Skarn forms along sedimentary contacts replacing ls. Shears and quartz veins contain auriferous and argentiferous py, po.	AR 14767, 12088
6	Silver Queen	82F/13E 082FNW220	P	Limited	Jurassic? quartz monzonite sills	Early Jurassic Rossland Group – calc. siltstone, arkose, quartzite, marble	qtz-gt-tr-act-bio-cc-cz-ep-kspar	py-po-sl-gl-tt-pyrargyrite-as	Ag-Pb-Cu-As-Zn-Sb	Silver-rich skarn. No anomalous gold values. Same sill suite as found at Heino-Money gold skarn.	Ray *et al.* (1985), p.35; 1986a, p.37; McClintock and Roberts, (1984)

(Appendix 1 continued)

Loc. No. in Fig. 3	Name(s)	NTS MINFILE	Type	Production (ore t)	Associated Intrusive Rocks	Host Rocks	Skarn Mineralogy	Opaque Mineralogy	Associated Metallic Elements	Comments	References
6	Heino-Money zone (Tillicum Mountain)	82F/13E 82K/4E 082FNW234	O	Bulk sample (3 356 t) Au - 31.9 g/t Ag - 30.9 g/t	Jurassic? quartz monzonite sills	Early Jurassic Rossland Group – tuff, basalt, calc. siltstone, argillite	qtz-gt-pyx-tr-act-bio-cz-cc-kspar	po-py-gl-sl-as-mc-tt-cp-em	Au-Ag-Cu-Pb-Zn-As	Two phases of precious metal deposition. First Au-As-Zn. Second Ag-Pb-As. Same sill suite as found at Silver Queen. Drill-indicated reserves: 181 400 tonnes @ 21 g/t Au.	Ray *et al.* (1985), p.35; 1986a, p.37; McClintock and Roberts, (1984); Northcote, (1983) CIM Paper 133A (1983); AR 12269, 7909
6	Hailstorm Mt. (Tillicum, Carribou)	82F/13E 082FNW255	O		Jurassic? quartz monzonite sills	Early Jurassic Rossland Group – calc. siltstone, marble, argillite, tuff	pyx-gt-act-cc-bio-qtz	py-po-gl-sl-as-cp-sb	Pb-Cu-As-Zn-Sb	Similar host and intrusive rocks as the Heino-Money zone.	Addie (1985), p.49; 1986, p.337; Ray *et al.* (1985), p.37; AR 11141, 12355
7	Salmo-Malarctic mines	82F/3E 082FSW001	P	(28 t) Ag - 36 359 g Pb - 431 kg Zn - 365 kg	Cretaceous Nelson batholith	Cambrian Laib Formation – Reeves limestone, dolostone, argillite, qtzt.	ol-serp-tc humite-pyx-qtz-wo	py-sl-gl-tt-po	Pb-Zn-Ag (minor Au)	Magnesian skarn deposits in 3 dolostone horizons. Upper is Zn rich. Middle is Ag rich. Lower is Pb-Zn-Ag rich.	AR 9053, 12 985; EMPR Exploration in B.C.. 1980, p.55
7	Jackpot	82F/6E 082FSW014	P	(56 820 t) Au - 31 413 g Ag - 8 500 kg	Early Cretaceous Hidden Creek granitic stock	Cambrian Laib Formation – Reeves limestone, quartzite, dolomite	'Calc silicate' skarn; wo	py-gl-native silver-tt-argentite-po-cp-sl	Au-Pb-Zn-Cu-Ag	Ore grades 0.61 g/t Au, 4.35 g/t Ag.	AR 11450, 10885; GEM 1974, p.68; GEM 1973, p.58; MMAR 1968, p.241
7	Texans	82F/3E 082FSW265	O		Early Cretaceous Nelson batholith, granodiorite	Early Cambrian Hamill Group – ls., qtzt., schist, argillite, greenstone, paragneiss	ep-tb-wo	py-po-sl-cp-mt	Au-Zn-Cu	Grab samples from dump assay 3-6 g/t Au.	AR 11440; MMAR 1901, 1928, 1929
8	Mormon Girl	82F/3W 082FSW002		(340 t) Au - 3 298 g Ag - 9 644 g	Cretaceous Nelson batholith	Cambrian Laib Formation – quartzite, limestone, argillite	ep-qtz-sch	py-po	Au-W-Ag-Mo-Pb	Skarn associated with late faulting and crosscutting lamprophyre and aplite dykes. Quartz veins have py, moly, gl.	AR 12758; GSC Memoir 94; GSC Memoir 172, p.89; GSC Memoir 308, p.158
8	Py	82F/3W 082FSW023	O		Cretaceous Nelson batholith	Cambrian Laib Formation – limestone, quartzite, argillite	tr-qtz-pyx	py-po-sl-gl	Zn-Pb-Ag	Chip samples assay 34 g/t Ag, 3.4% Pb, 5.1% Zn.	AR 2747; GEM 1970, p.443; GSC Map 299A, 1090A, 1145A
9	Orinoco	82F/6W 082FSW082	P	(45 352 t) Au - 7 651 g Ag - 950 010 g Cu - 673 t	Cretaceous Nelson granodiorite; feldspar porphyry sills	Early Jurassic Hall Formation – quartzite, argillite, amphibolite, feldspar porphyry	gt-ep-act-qtz-cc	mt-po-py-cp-bn	Au-Cu-Ag		AR 927; GSC Paper 49 - 22; GSC Paper 52 - 13

(Appendix 1 continued)

Loc. No. in Fig. 3	Name(s)	NTS MINFILE	Type	Production (ore t)	Associated Intrusive Rocks	Host Rocks	Skarn Mineralogy	Opaque Mineralogy	Associated Metallic Elements	Comments	References
9	Elk	82F/6W 082FSW282	P	(154 t)	Cretaceous Nelson batholith	Early Jurassic Hall Formation – qtzt., ls., arg.	gt-ep	cp-py-moly-gl-sl-po-mt	Au-Cu-Mo-Pb-Zn-Ag	Grab sample assayed 1.02 g/t Au, 106 g/t Ag, 7.89% Cu.	AR 8661; GSC Paper 49 - 22; GSC Paper 52 - 13
10	Sir Douglas Haig	82F/4W 082FSW163	P	(7 t) Ag - 187 g Cu - 22 kg	Cretaceous Nelson granodiorite, quartz diorite	Pennsylvanian ? Mount Roberts Formation – slst., qtzt., greywacke, slate, pebble conglom., ls.	hb-ep-gt-feldspar-qtz	mt-py-po-cp-bm	Cu-Bi-Ag	Silver-rich skarn along intrusive contact.	EMPR Bulletin 74; GSC Summary Report 1906, p.62
11	Monarch	82F/6E 082FSW211	O		Cretaceous Nelson granite	Early Jurassic Rossland Group Elise Formation – volcanics and Hall Formation seds., ls. and arg.	ep-gt-kspar	py-po-moly-cp-gl-sl	Au?-Pb-Zn-Ag-Mo-Cu	Assays from trenches 1.66% Cu, 0.066% MoS_2, only trace gold reported, probable silver-enriched skarn.	MMAR 1967, p.243; 1968, p.240
12	Rely 1	82F/3W 082FSW266	P	(55 t) Au - 560 g Ag - 4 976 g	Cretaceous Nelson granodiorite. Diorite, feldspar porphyry, sill	Early Jurassic Archibald Formation – argillite, greywacke, limestone, basalt	qtz.	py-po-gl-cp-sl-gold	Au-Pb-Zn-Ag-Cu	Grab sample: 14 g/t Au, 150 g/t Ag, 1.8% Pb, 3.2% Zn, tr. Cu. Hornfels and local skarn development at contact between limestone and diorite sill.	AR 12762; EMPR Exploration in BC 1983, p.59
13	REM (EBL)	82M/5W 082M 051	O		Granodiorite-diorite dykes	Paleozoic Eagle Bay assemblage – qtz.-sericite schist, limestone, qtz. bio. schist	gt-ep-chl-qtz-amph	py-po-cp-mt-sl-gl	Au-Cu-Pb-Zn-Ag-Mo	Low Au-Ag reported in soils and rock. Skarn replaces ls. Sulphides in qtz-cc veins, massive lenses and skarn.	AR 14950, 11386
14	Trio	82M/14W 082M 142	O		Fine to medium grained granite, quartz monzonite	Shuswap Meta. Complex – amphibolite, qtz. feld., bio. schist and gneiss, hornfels, skarn	NR	py-cp	Ag-Pb-Zn-Mo-W	Adjacent to 082M 184 - Hydro. Grab sample assayed: Cu - 7.9%; Zn - 0.03%; Ag-85 g/t; Au - 0.03 g/t Sulphides in skarn.	EMPR Exploration in BC 1975, p.E60; GSC Map 48 - 1963
14	Hydro	82M/14W 082M 184	O		Fine to medium grained granite, quartz monzonite	Shuswap Meta. Complex – amphibolite, qtz. feld.-bio. schist and gneiss, hornfels, skarn	Amphibolite-hornfels	cp-py-po-moly	Ag-Cu-Mo-W	Sulphides in quartz veins cutting skarn. Possible metamorphic skarn assemblage. 7 metre channel sample assayed: Ag - 2 g/t; Cu - 0.34%; Mo - 0.094%; WO_3 - 0.01%.	AR 7127; EMPR Exploration in BC 1978, p.E116
15	Sorcerer Creek (Ruger)	82M/8E 082M 156	O		Middle Jurassic (?) Bigmouth Creek stock	Paleozoic Lardeau Group – carbonaceous phyllite, limestone, quartzite	gt-pyx-cc-wo-sch	mt-py-po-moly-cp	W-Cu-Mo	Skarn occurs parallel to bedding at limestone-phyllite contacts. Sulphides in skarn and crosscutting faults.	AR 8591; EMPR Exploration in BC 1980, p.142

(Appendix 1 continued)

Loc. No. in Fig. 3	Name(s)	NTS MINFILE	Type	Production (ore t)	Associated Intrusive Rocks	Host Rocks	Skarn Mineralogy	Opaque Mineralogy	Associated Metallic Elements	Comments	References
16	Liquid Sunshine (Happy John)	92C/15W 92F/2W 092C 008	O		Dacite-andesite dykes	Late Triassic Quatsino limestone, Jurassic Bonanza volcanics	gt-pyx-act-chl-ep-qtz	cp-mt-py-po	Au-Ag-Cu-As-Zn	Skarn at limestone-volcanic contact; Assays from 32 samples: Ag - 5.8 - 57.8 g/t; Au - 0.033 - 10.0 g/t; Cu - 0.23 - 5.5%.	Shangri-La Minerals Ltd. Report; Muller (1982); MMAR - 1928
17	Blue Grouse (Cowichan Lake)	92C/16E 092C 017	P	(249 298 t) Au - 218 g Ag - 2 509 kg Cu - 6 815 t	Feldspar porphyry swarm	Late Triassic Franklin Creek (Karmutsen) Formation – limy tuffs, mafic flows, limestone	gt-ep-act	cp-po-py-mt-sl	Cu-Ag-Zn	Bedded sulphides. Replacement related to feldspar porphyry intrusions. Silver-enriched copper skarn.	AR 8896, 616; GEM 1977, p.E107, GEM 1979, p.126; EMPR Bulletin 37 - 54
18	Beano (Bingo)	92E/15W 092E 002	P	(21 t) Au - 3 297 g Ag - 1 400 g Cu - 33 kg	Jurassic diorite; later rhyolite porphyry sill	Triassic – Jurassic Quatsino limestone and Bonanza volc. – fine-grained dacitic-andesitic tuff, limestone	act-pyx	po-ap-cp-mt-hd	Au-Ag-Cu-Bi-Te-Co	Chlorine-rich ferrohastingsite and actinolite replaces ls. and volc. (?). Similar to 092L-068, 127. Grab sample of po-amph skarn assayed: Au - 25 g/t; Ag-1 g/t; Cu - 0.07%, Co - 162 ppm; Bi - 150 ppm.	AR 12772, 12573, 5079; Stevenson (1950); Muller *et al.* (1981); GSC Memoir 272, p.50.
19	Geo (Star of the West)	92E/15E 092E 010	P	(1 t) Au - 31 g	Jurassic (?) granodiorite	Late Triassic Quatsino limestone	gt-ep-qtz	cp-as-mt-gl-bn-po-py-az	Au-Ag-Cu-As	Skarn along limestone-granodiorite contact. 700 kg bulk sample assayed: Au - 4.6 g/t; Ag - 10.3 g/t; Cu - 5.2%.	GEM 1970, p.284; Muller *et al.* (1981); MMAR 1962, p.104
20	Dewdney (Indian Chief, Blackbird, Prince)	92E/8W 092E 011 092E 032	P	(73 608 t) Au - 22 457 g Ag - 1 707 kg Cu - 1 102 t	Jurassic quartz diorite; 42 Ma porph. dyke at mine portal; 12 Ma (?) granodiorite. All spatially associated with skarn	Paleozoic Sicker Group or Jurassic Bonanza Group – limestone, lithic tuffs, basaltic – andesitic volcanics	gt-ep-pyx-wo	mt-cp-bn-gl-po-sl	Au-Cu-Ag	Possible Fe and Cu skarn mineralization with skarn forming 'mineralized pockets' along limestone-intrusive contacts.	AR 463; Muller *et al.* (1981); GEM 1973, p.29
20	Hesquiat (Brown Jug, Thelma)	92E/8W 092E 016 092E 031	O		Quartz diorite – diorite	Paleozoic Sicker Group and Late Triassic Karmutsen Formation – tuff, limestone, volc.	gt-qtz-cc-ser-ep	sl-py-po-gl-cp-mal-ct	Au-Zn-Cu-Ag	Mineralization occurs in footwall of a shear zone at volcanic-limestone contact, and in sulphide veins.	Muller *et al.* (1981); AR 4103
21	Silverado (Danzig)	92E/9W 092E 017	P	(130 t) Au - 5 567 g Ag - 10 294 g Cu - 87 kg	Jurassic – Early Tertiary granodiorite (?)	Metavolcanics, limestone	pyx-gt-ep-qtz-cc	sl-cp-po-mt	Au-Ag-Cu-Zn	Skarn crosscut by faults. Assays over widths up to 2 m.: Au – tr- - 3.1 g/t; Ag – tr - 223 g/t; Cu – <0.3 - 11.1%; Zn – <0.3 - 55.8%; Pb – <0.3 - 0.32%.	Muller *et al.* (1981); CIM Trans. Vol. 72, p.116; Carson (1973)

(Appendix 1 continued)

Loc. No. in Fig. 3	Name(s)	NTS MINFILE	Type	Production (ore t)	Associated Intrusive Rocks	Host Rocks	Skarn Mineralogy	Opaque Mineralogy	Associated Metallic Elements	Comments	References
22	Nor (Tony)	92F/3W 092F 003 092F 004	O		Early Tertiary granodiorite?	Late Traissic Quatsino limestone pendant. Andesites of uncertain age	pyx-gt-plag-ep	mt-cp-po-bn Mn minerals associated with younger porphyries	Au-Ag-Cu-Mn	Distal to Brynnor magnetite deposit. Mineralization at ls.-andesite contacts. Assays yielded: Au - 3.4-51.4 g/t; Ag - 0.31-1.6 g/t in gt skarn.	AR 14704; Groves (1985)
23	Little Billie (Little Billy)	92F/15E 092F 105	P	(63 700 t) Au - 363 kg Ag - 1 198 kg Cu - 819 098 kg	Mesozoic granodiorite stock	Late Triassic Marble Bay limestone	gt-wo-pyx-ep-amph-cc-qtz-id-sch	py-bn-cp-moly-po-mt-sl-gl-Ag tellurides	Au-Ag-Cu-Zn-Pb-Te	Skarn follows dip of mb-granodiorite contact near centre of marble alteration halo in limestone.	McConnell (1914); Stevenson (1945); Peatfield (1987); Ettlinger and Ray (1988)
23	Texada Iron Mines (Lake, Paxton, Prescott, Yellow Kid)	92F/10E 092F 106 092F 107 092F 258 092F 259	P	(20 801 000 t) Au - 888 kg Ag - 23 644 kg Cu - 26 740 t	Mesozoic Gillies quartz monzodiorite stock	Late Triassic Texada Formation – andesites/ basalts and Marble Bay limestone	ep-gt-pyx-cc-qtz-amph-sc-ab	mt-py-cp-po-sl-ery	Au-Ag-Cu-Zn-Co-As	Skarn occurs in variable amounts within qtz. monzodiorite, ls., and volcanics. Gold occurs in late, cp-rich sulphide pods replacing marble.	Meinert (1984); McConnell (1914); Peatfield (1987)
23	Cornell	92F/10E 092F 112	P	(40 700 t) Au - 471 kg Ag - 2 194 kg Cu - 1 369 t	Mesozoic porphyritic diorite/gabbro	Late Triassic Marble Bay limestone	pyx-gt-ep-cc-serp.-sch.	bn-cp-py-mt-moly-tt-silver	Au-Ag-Cu-Mo	Au associated with bn-rich zones along limestone – diorite contact.	McConnell (1914); Peatfield (1987); N. Miner Feb. 7, 1985; N. Miner Dec. 20, 1984
23	Security (Florence)	92F/10E 092F 269	O		Mesozoic porphyritic diorite/gabbro	Late Triassic Texada Formation andesites/basalts and Marble Bay limestone	gt-ep-pyx-wo	mt-py-cp-moly-sl-bn-chc (?)	Au-Ag-Cu-Zn-Mo-Co	Skarn formed along faulted volc.-limestone contacts. Au occurs in cp-rich sulphide pods and in cross-cutting quartz filled structures. Assays over 1.2 m intervals yielded: Au - 21.5 g/t; Ag - 29.3 g/t; Cu - 1.59%; Co - 310 ppm.	Lakes (1930); Ettlinger and Ray (1988)
23	Marble Bay	92F/15E 092F 270	P	(199 200 t) Au - 1 544 kg Ag - 12 621 kg Cu - 6 789 t	Mesozoic diorite porphyry stock and associated dykes	Late Triassic Marble Bay limestone	gt-ep-pyx-qtz-tr (wo ?)-cc	cp-bn-moly-py-trace mt-po-tt-silver	Au-Ag-Cu-Mo	Au associated with cp-bn occurring in gt-pyx-cc and tr (wo ?). Similar to 092F 105 in silicate-sulphide assemblage, and massive ls. host; but associated with diorite.	McConnell (1914); Peatfield (1987)
23	Copper Queen	92F/10E 92F/15E 092F 271	P	(4 075 t) Au - 47 kg Ag - 355 kg Cu - 161 t	Mesozoic granodiorite and diorite porphyry dyke	Late Triassic Marble Bay limestone	gt-pyx-ep-cc-sch	bn-cp-tt-moly-silver	Au-Ag-Cu-Mo-W	Skarn reported along limestone-diorite porphyry contacts.	McConnell (1914); Peatfield (1987); GEM 1979, p.132

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Loc. No. in Fig. 3	Name(s)	NTS MINFILE	Type	Production (ore t)	Associated Intrusive Rocks	Host Rocks	Skarn Mineralogy	Opaque Mineralogy	Associated Metallic Elements	Comments	References
24	King Midas	92F/9E 092F 115	O		Cretaceous (?) Coast Range granodiorite	Roof pendant of Jarvis Group seds.	cc-ep-gt	mt-py-cp-native Cu-hm	Au-Ag-Cu	Mineralization in closely spaced irregular fractures. Grab sample assayed: Au – 0.6 g/t; Ag – 377 g/t; Cu – 17.2%.	MMAR 1937, p.F31; MMAR 1950, p.170
24	Cambrian Chieftain (Cambrian Chief, Ham Group)	92G/12W 092GNW011	P	(1 421 t) Au - 529 g Ag - 125 kg Cu - 74 t	Cretaceous or earlier Coast Range granodiorite, andesite and diorite porphyry dykes	Cretaceous or earlier pendant of Jarvis Group sediments – chert, limestone, metavolcanic, argillite	ep-gt-dolo	po-cp-py-mt-sl-moly	Au-Cu-Zn-Ag	Vein-like sulphides in skarn.	AR 11472; EMPR Bulletin 39, p.36; EMPR Bulletin 40, p.97
25	Roadside (Florence, Malaspina, John Bull)	92F/15E 092F 147	P	(47 t) Ag - 6 221 g Cu - 2 149 kg Zn - 4 781 kg	Coast Range granodiorite and numerous dykes, sills and small plugs from pegmatite to gabbro	Limestone inliers	gt-ep-chl-qtz	mt-po-cp-sl-py-bn-gl	Ag-Cu-Zn	Banded siliceous skarn replaces crystalline limestone. Sulphides concentrated in skarn along granite-limestone contact.	AR 6258, 4961; GEM 1977, p.E116
25	Royal Arch	92F/15E 092F 148	O		Cretaceous (?) Coast Range batholith and later porph. dykes	Limestone inliers	NR	sl-py-gl-cp-po-bn	Au-Cu-Ag-Zn	Skarn along limestone-granite contact.	AR 4961; GEM 1974, p.189; GEM 1977, p.E116
26	Jane - Toni - Kathy - Larry (Skarn, Nor)	92F/1W 092F 182	O		Jurassic Island intrusion – granite – quartz monzodiorite	Paleozoic Sicker Group – Buttle Lake limestone, and Myra volcanic/argillite	gt-ep-pyx-amph-chl-prh-sph-qtz-cc	py-cp-mt-hm	Au-Ag-Cu-Zn-Co-As-Bi	Massive coarse garnet skarn. Grab sample assayed: Au – 0.73 g/t; Ag – 3.0 g/t; Cu – 0.073%; Zn – 0.057%; As – 132 ppm; Bi – 54 ppm.	AR 14729; GSC Paper 80 - 16; GSC Paper 79 - 30
27	Egg (Copper)	92G/13W 092GNW017	O		Coast Plutonic Complex – quartz diorite dyke	Pendant of Jarvis Group– andesite/ dacite tuff, basalt, argillite, chert	NR	mt-po-py-cp-sl	Au-Ag-Cu	Skarn in roof pendant.	GEM 1972, p.278; GEM 1973, p.242; EMPR Bulletin 39, p.37
28	Copper Duke, (Swayne Copper, Mtn. Lion, Lynn Creek)	92G/6E 092GSW001	O		Diabase	NR	NR	mt-cp-sl-gl-po-py	Au-Cu-Ag	Skarn reported in Lynn Creek group; mineralization in quartz veins in diabase.	GSC Memoir 335, p.189
29	Chicago (Law's Camp)	92H/10W 092HNE016	O		Late Jurassic Eagle granodiorite	Late Triassic Nicola Group – limestone with interbedded mica, chlorite and talc schists	gt-ep-amph	po-py-cp-gl-sl-mt	Au-Pt-Cu-Zn-Pb	Skarn and sulphides in limestone. Copper-rich scarn assayed 137 g/t Pt.	Rublee (1986); GSC Memoir 243, p.98; GSC Memoir 26, pp.162, 164

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Loc. No. Fig. 3	Name(s)	NTS MINFILE	Type	Production (ore t)	Associated Intrusive Rocks	Host Rocks	Skarn Mineralogy	Opaque Mineralogy	Associated Metallic Elements	Comments	References
29	St. George (Law's Camp, St. Lawrence, Liverpool)	92H/10W 092HNE064 092HNE065 092HNE066	O		Late Jurassic Eagle granodiorite	Late Triassic Nicola Group – limestone, mica/ dolo/talc schists	gt-ep-amph-cc-qtz	po-py-cp-gl-sl-mt	Au-Ag-Cu	Replacement deposits in limestone. Ore follows fractures from granite porphyry into country rock.	MMAR 1929, p.279; GEM 1972, p.132
30	Mascot Fraction (Hedley Mascot Gold Mines)	92H/8E 092HSE036	P	(618 640 t) Au - 6 937 kg Ag - 1 707 kg Cu - 870 617 kg	Early Jurassic Hedley intrusions – porph. quartz diorite/gabbro sills and dykes	Late Triassic Nicola Group, Hedley formation – siltstone, limestone, conglomerate, tuff	pyx-gt-wo-bio-kspar-sc-cc-qtz-prh-ax-ap	as-po-cp-py-mt-bn-hd-ml	Au-Ag-Cu-Zn-Bi-As-Co-Te	Au concentrated within 100 metres of skarn – marble contact. Gold-arsenic-rich skarn mineralization.	Ray *et al.* (1988, 1987, 1986b); Dolmage and Brown (1945); Billingsley and Hume (1941)
30	Nickel Plate (Kingston)	92H/8E 092HSE037 092HSE038 092HSE062	P	(2 986 209 t) Au - 41 705 kg Ag - 4 160 kg Cu - 981 030 kg	Early Jurassic Hedley Intrusions – porph. quartz diorite/gabbro sills and dykes	Late Triassic Nicola Group, Hedley formation – siltstone, limestone, conglomerate, tuff	pyx-gt-wo-bio-kspar-sc-cc-qtz-ap-prh-ax	as-po-cp-py-mt-bn-hd-ml	Au-Ag-Cu-Zn-Bi-As-Co-Te	The Nickel Plate and Mascot Fraction form part of a single, westerly dipping gold-arsenic-rich deposit.	Ray *et al.* (1988, 1987, 1986b); Dolmage and Brown (1945); Billingsley and Hume (1941)
30	French (Oregon)	92H/8E 092HSE059	P	(68 464 t) Au - 1 362 kg Ag - 181 kg Cu - 20 535 kg	Early Jurassic Hedley intrusions – porphyritic qtz. diorite sills	Late Triassic French Mine formation – limestone, breccia, and conglomerate. Late Triassic Peachland Creek formation – mafic tuffs	pyx-gt-wo-qtz-bio-kspar-cc-tr-sch-ax	po-cp-bn-py-cu-as	Au-Ag-Cu-W-As-Mo-Bi-Co-Sb	Mineralization hosted in same stratigraphic horizon as the Goodhope mine. Au concentrated in hinge of broad anticline.	Ray *et al.* (1988, 1987, 1986b); Northern Miner October 14, 1982
30	Good Hope I	92H/8E 092HSE060	P	(11 410 t) Au - 178 kg Ag - 120 kg Cu - 602 kg	Early Jurassic Hedley intrusions – quartz diorite	Late Triassic Nicola Group – tuff, argillite, limestone	ep-pyx-gt-qtz-cc-sch	as-py-cp-po-moly-hd	Au-Ag-Cu-W-As-Bi-Mo	Mineralization hosted in same stratigraphic horizon as French mine and contained in steeply dipping fault cutting skarn.	Ray *et al.* (1988, 1987, 1986b); AR 8787
30	Florence	92H/8E 092HSE061	O		Early Jurassic Hedley Intrusions – porphy. qtz. diorite dykes	Late Triassic Nicola Group, Stemwinder Mountain formation – sediments	pyx-gt	as-py	Au-As	Skarn near limestone-dyke contact.	EMPR Open File 87-10; GEM 1979, p.144; GEM 1973, p.136
30	Duffy	92H/8E 092HSE063	O		Early Jurassic Hedley intrusions – qtz. diorite	Late Triassic Nicola Group – limestone, siltstone, argillite, tuff	pyx-gt	py	Au-Ag-Cu	Steeply dipping Bradshaw fault cutting skarn.	EMPR Open File 1987-10; GEM 1973, p.136; EMPR Exploration in BC 1979, p.144

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Loc. No. in Fig. 3	Name(s)	NTS MINFILE	Type	Production (ore t)	Associated Intrusive Rocks	Host Rocks	Skarn Mineralogy	Opaque Mineralogy	Associated Metallic Elements	Comments	References
30	Canty (Pittsburg, Boston Greenwood)	92H/8E 092HSE064	P	(1 483 t) Au - 16 kg	Early Jurassic Hedley intrusions – quartz diorite sills	Late Triassic Whistle Creek formation – andesite, tuff, limestone, siltstone	pyx-cc-qtz-gt-ep-alb-sc-kspar	as-py-cp-po	Au-W-As-Co-Ag	Mine adjacent to the skarn in Cahill Creek fracture zone.	Ray *et al.* (1988, 1987, 1986b); Northern Miner May 19, 1983, October 14, 1982; NMI 92H/8-AU5
30	Peggy (Hedley Amalgamated, Whirlwind)	92H/8E 092HSE066	P	Limited	Early Jurassic Hedley intrusions (Stemwinder stock). Quartz diorite	Late Triassic Nicola Group, Stemwinder Mountain formation – arg. – siltstone and thin limestone beds	pyx-gt-cc	py-as-po-cp-sl	Au-Cu-Co-As	Mineralization in fault zone adjacent to Stemwinder stock.	Ray *et al.* (1988), (1987)
30	Lion	92H/8E 092HSE110	O		Early Jurassic Similkameen granodiorite	Late Triassic Nicola Group – limestone, argillite, quartzite	qtz-pyx-gt-cc	as-po-py-cp	Au-As-Cu-Ag	Limestone replaced by skarn adjacent to granodiorite contact. Au with arsenopyrite.	GEM 1970, p.394; AR 2955
30	Hedley Star (XR-1)	92H/8E 092HSE154	O		Early Jurassic Hedley intrusions quartz diorite	Paleozoic Apex Mountain Group – chert, argillite, volcanics	pyx-gt	py-as	Au-As	Au concentrated at chert/ quartz diorite contact.	AR 14522
30	Hedley North	92H/8E 092HSE156	O		Early Jurassic Similkameen granodiorite. Early Jurassic Hedley intrusions – qtz. diorite sills	Late Triassic Nicola Group – argillite, quartzite, limestone	gt-wo-pyx-sc-cc-qtz-ep	py-po-as-gl-cp	As-Pb	Skarn in limb of broad anticline.	AR 11186 AR 14879
31	Sunset (Silent Friend, Hope, Ross)	92H/3E 092HSW029	O		Coast Range granodiorite, younger biotite-quartz diorite	Pendant of Carboniferous-Permian Hozameen Grp. Andesite, limestone, greywacke, mudstones	qtz-gt-ep-cb	sl-cp-gl-mt-hm-py	Au-Ag-Cu-Pb-Zn-Cd	Skarn near nose of syncline. Assay over 1.5 m. yielded: Au - 1.0 g/t; Ag - 100.8 g/t; Cu - 1.6%; Pb - 0.87%; Zn - 20.4%; Cd - 0.14%.	AR 4719, 1195; GEM 1973, p.124
32	Lucky Mike (Last Chance)	92I/7E 092ISE027	P	(24 t) Au - 62 g Ag - 4 262 g Pb - 795 kg Cu - 876 kg	Jurassic (?) acidic dykes, granite-diorite. Tertiary Rey Lake stock distal to deposit	Late Triassic Nicola Group – greenstone and pyroclastics, limestone, breccia and agglomerate	gt-ep-cc-pyx-sch	py-po-cp	Au-Cu-Pb-Zn-Ag-W	Cockfield (1948) suggests low temp. sl-gl-tt and cp-gl-sl veins south of this property may represent a temp. zonation about a concealed pluton at or below this showing.	Cockfield (1948); AR 1795

(Appendix 1 continued)

Loc. No. in Fig. 3	Name(s)	NTS MINFILE	Type	Production (ore t)	Associated Intrusive Rocks	Host Rocks	Skarn Mineralogy	Opaque Mineralogy	Associated Metallic Elements	Comments	References
33	Natch 1-4 (Nahatlach)	92I/4E 092ISW090	O		Cretaceous Coast plutonic complex quartz monzonite/ diorite	Jurassic (?) Ladner Group (?) – metasediments and volcanics	act-gt-bio-qtz-cc-kspar	as-py	Au-As-Ag	Limestone beds adjacent to intrusion have undergone contact metamorphism. Assay over 5.48 m of drill core yielded: Au - 4.0 g/t; Ag - 4.8 g/t.	AR 13634; GEM 1983, p.272
34	Seneca (Crown, Rex, Gold King, Tenquille Group)	92J/10W 092JNE049 092JNE053 092JNE054	O		Cretaceous Bendor batholith – quartz monzonite-granodiorite. Quartz-feldspar porphyry dykes	Late Triassic Cadwallader Group – limestone, tuff, quartzite, chert, and agglomerate	gt-pyx-ep-cc-qtz	mt-py-cp-sl-po-gl-hm-pyr-native silver	Au-Cu-Pb-Zn-Ag-As-Sb-Ni	Dolomitization and silicification of limestone in extensively faulted area. Assay from 4.5 tonne sample yielded: Ag - 890 g/t; Pb - 4.1%; Zn - 3.2%.	GSC Paper 73 - 17; AR 365, 10299; GSC Summary Report 1924, p.96A
35	Axe (London, Green Lake)	92J/2W 092JSE001	O		Granodiorite sills, schistose granitic rocks	Late Paleozoic or younger – metavolcanics, sediments, schists, crystal tuff	ep-cc-qtz	mt-py-cp-mal-moly	Cu-Mo	Skarn formed in volcanics. Sulphides in magnetite-skarn and schistose granodiorite.	MMAR 1963, p.94; GEM 1971, p.305
36	Copper Bear (Eagle, Zip, Ax, Lake)	92J/7E 092JSE008	O		Feldspar porphyry and diorite dykes, hornblende diorite	Late Triassic Pioneer Formation – limestone, greenstone	gt-ep	py-cp-mt-sl-po-as	Au-Ag-Cu-Zn	Massive sulphides at diorite-skarn-mb contact. Outcrop-scale folds have sulphide-rich cores outward to gt-ep skarn grading into greenstone.	AR 9[illegible]03; GSC Paper 73 - 17; GEM 1969, p.189
36	Marjory (Margery)	92J/7E 092JSE012	O		Diorite and porphyry dykes	Triassic limestone, argillite, quartzite	NR	py-cp-mt-sl-as	Au-Pt	Mineralization in shear zones at intersections with limestone.	GSC Paper 73 - 17; GSC Summary Report 1917B, p.19; GSC Summary Report 1924A, p.89
36	Owl Mountain (North Star)	92J/7E 092JSE014	O		Coast plutonic complex, Spetch Creek pluton – granodiorite	Pendant of Late Triassic Cadwallader Group – andesite tuff, breccia, and metaseds.	amph-pyx-ep	mt-py-as-sl-annabergite	Au-Ag-As-Zn-Co	Skarn along granodiorite contacts. Au in skarn generally ranges from trace - 2.2 g/t with values up to 182 g/t reported.	AR 15597; GSC Paper 73 - 17
37	Nat #4 (Great Gold Group)	92K/3W 092K 141	O		Coast plutonic complex (?) granitic rocks	Late Triassic Karmutsen Formation – volcanics. Quatsino Formation – limestone	NR	py, cp	Au-Ag-Cu-W-Zn	Channel sample over 9.14 m in skarn yielded: Au - 2.88 g/t; Ag - 35.7 g/t; Cu - 2.34%; Zn - 0.25%; W - 0.1%.	AR 16142

(Appendix 1 continued)

Loc. No. Fig. 3	Name(s)	NTS MINFILE	Type	Production (ore t)	Associated Intrusive Rocks	Host Rocks	Skarn Mineralogy	Opaque Mineralogy	Associated Metallic Elements	Comments	References
38	Old Sport	92L/6E 092L 035	P	(2 657 593 t) Au - 3 869 kg Ag - 11 731 kg Cu - 41 193 t	Middle Jurassic Coast Copper Stock – diorite/ gabbro	Late Triassic Karmutsen Formation – volcanics and Quatsino Formation – limestone	gt-ep-cc-amph-pyx-chl-qtz	mt-po-cp-bn-py-as	Au-Ag-Cu	Replacement of limestone interbed in andesitic volcanics. Possible Cu-rich member of Fe-Cu skarn zonation in Benson Lake area.	MMAR 1960, p.100 - 101; GEM 1972, p.289; GSC Bulletin 172, p.80
38	Merry Widow (Kingfisher, Raven)	92L/6 092L 044 092L 045 092L 046	P	(3 371 813 t) Fe conc. 1 683 507 t	Middle Jurassic Coast Copper stock – gabbro	Late Triassic – Quatsino limestone. Early Jurassic Bonanza volcanics – limestone, crystal tuff, siliceous tuff, flows	gt-amph-ep-pyx-qtz-ap-sch	mt-py-cp-sl-ilm-po-as-ery-mc-hm	Au-Ag-Cu-Co-As-Zn	No historical precious metal production; however, 7 Au-rich sulphide samples averaged 19.2 g/t. Surface gossan above mt-cp bx. assayed: Au - 32.0 g/t; Ag - 200 g/t; Cu - 17.2%; Zn - 2.9%; Co - 1 600 ppm; As - 0.2%.	Ettinger and Ray (1988); MMAR 1961, p.96; GSC Summary Report 1929A, p.94; Sangster (1969); Meinert (1984)
38	Benson Lake (Independent)	92L/6E 092L 091	O		Jurassic quartz diorite	Late Triassic Karmutsen and Quatsino Formations – volcanics, limestone	gt-ep-cc	cp-mt-bn-py-po-as	NR		Laznicka (1973); MMAR 1968, p.A53; GSC Summary Report 1929A, p.126
39	Artlish (Hiller, A-25)	92L/2W 092L 068 092L 127	O		Jurassic Zeballos batholith – granitic-quartz dioritic	Early Jurassic Parsons Bay or Bonanza Formation – argillite, limestone, siltstone, andesite, tuff	amph-pxy-cc-qtz-chl-sc	po-mt-cp-py-hd	Au-Ag-Cu-Bi-Te-B	Chlorine-rich ferrohastingsite and actinolite replaces ls. and tuff. Similar to 092E 002. Au is hosted by mt-po skarn but is highly enriched in shear zone cutting skarn.	GSC Memoir 272; Falconbridge Ltd., company reports
40	Lake (North Shore, Jean)	92L/12W 092L 077	O		Porphyry dykes	Late Triassic Karmutsen Formation – volcanics, limestone	NR	mt-cp-sl-gl	Ag-Cu-Pb-Zn	Skarn and limestone replacement mineralization. Assay over 1.8 m in skarn yielded: Au - tr; Ag - 12.3 g/t; Cu - 1.63%. Assay over 0.46 m in replacement mineralization yielded: Au - tr; Ag - 187 g/t; Cu - 0.07%; Pb - 3.26%; Zn - 6.46%.	GSC Paper 74- 8, p.60; AR 1610; MMAR 1968, p.94
41	Hab (Bob, Bonanza Mine)	92L/7W 092L 164	P	(4 768 t) Ag - 41 149 g Cu - 117 244 kg	Jurassic equigranular granodiorite, porphyritic quartz diorite	Late Triassic Karmutsen Formation – volcanics and interbedded limestone	gt-ep-act-chl-qtz-pyx	mt-cp-py-po-sl-hm	Au-Ag-Cu	Sulphides disseminated in skarn which occurs in a folded inlier within a Jurassic intrusion.	AR 5394, 6267; MMAR 1968, p.100

(Appendix 1 continued)

Loc. No. In Fig. 3	Name(s)	NTS MINFILE	Type	Production (ore t)	Associated Intrusive Rocks	Host Rocks	Skarn Mineralogy	Opaque Mineralogy	Associated Metallic Elements	Comments	References
42	Roncam (Daisy, Ducharne, Copper Queen)	92N/IE 092N 026	O		Post Early Cretaceous Coast Range diorite/ granodiorite stocks and dykes	Triassic argillite, limestone, andesite, agglomerate	gt-sch	cp-po-moly-py-as-mal-gl-sl	Au-Cu-Mo-W-Ag-Ni-Co-V	Mineralization occurs at or near limestone lens. Au reported but unconfirmed. Drill core assays: over 27.4 m: Cu - 0.127%; over 15.2 m: MoS_2 - 0.325%; over 54.9 m: WO_3 - 0.235%.	AR 8682, 5712; GSC Summary Report 1924, p.69
43	Silver	92P/9W 092P 008	O		Late Triassic – Early Jurassic Thuya batholith (?) – pyroxene microdiorite	Late Triassic Nicola Group – volcanics, sediments	NR	mt-po-py-cp	Au-Ag-Cu	Sulphides in skarn and fault zones.	GEM 1970, p.312
44	Mayday	92B/8W 092B 004	O		Granite Mountain – granitic intrusion	Permian Cache Creek Group – meta-tuffs, volc., breccia, marble	gt-pyx-ep	mt-hm-cp-py-moly	Cu-Mo	Skarn and quartz veins in conformable lenses in marble and schist.	GEM 1972, p.335; 1969, p.338; GSC Map 12 - 1959
45	Tarn, And, Also (Miller claims)	93B/16E 093B 057	O		Mesozoic biotite-diorite and biotite-horblende diorite	Late Triassic – Early Jurassic Takla Group – greenstone, andesite, sediments	pyx-gt-id-ep	py-po-cp-chc-moly	Au-Cu-Mo-Ag	Country rock adjacent to diorite silicified, hornfelsed and replaced by skarn. Assay over 0.3 m across skarn: Au - 1.2 g/t; Ag - 15.7 g/t; Cu - 2.44%.	AR 9891
46	GG	93E/12E 093E 006	O		Post-Middle Jurassic Coast intrusion and Pre-Middle Jurassic Tahtsa complex (?) diorite/quartz diorite	Middle Jurassic Hazelton Group – flows, ls., meta-arg, silicified seds.,up to amphibolite grade metamorphism	wo-pyx-gt-qtz-cc-sph-ap	cp	Cu-Bi		EMPR Bulletin 42, pp.6 - 16; GEM 1969, p.76
47	Park	93E/6W 093E 102	O		Mesozoic – Cenozoic eastern margin of Coast Complex – qtz. dior./qtz. monz. rhyolite dykes and sills	Paleozoic (?) Gamsby Group – dacite/andesite, phyllite, siltstone, limestone, gneiss, schist metamorphosed to possibly amphibolite grade	gt-ep-wo	mt-cp-bn-sl-gl	Au-Cu-Ag	Skarn primarily hosted by phyllite. Wo-bn occurs in or near small mb lenses in phyllite; whereas, gt-ep-cp occurs near intrusive contacts. Sulphides favour wo skarn. Reported assays: Au up to 1.1 g/t; Ag: 243 g/t and Cu: 2.57% over 16 m.	AR 12209, 11172

(Appendix 1 continued)

Loc. No. in Fig. 3	Name(s)	NTS MINFILE	Type	Production (ore t)	Associated Intrusive Rocks	Host Rocks	Skarn Mineralogy	Opaque Mineralogy	Associated Metallic Elements	Comments	References
47	Mumbo	93E/5E 093E 111	O		Eocene Coast plutonic complex granite/quartz monzonite	Paleozoic Gamsby Group – felsic/mafic tuffs, volcanic ss, ls., metamorphosed to greenschist facies	gt-amph-pyx-ep-chl	cp-mal-mt-po	Ag-Cu	Skarn partly replaces limestone. Copper skarn with low reported Au-Ag. Assays up to Cu - 1.63%; Ag - 34.3 g/t (separate samples).	AR 8913
48	Samson (Giscome, Ace, Eagle)	93J/1W 093J 001	O		Tertiary porphyry granite and felsite. Older(?) serpentinite gabbro, diorite, dacite, granite	Mississippian Slide Mountain Group – ls., arg., andesite. Wolverine Complex gneiss. Metamorphism from zeolite to greenschist grade	gt-ep-tr-qtz-cc-chl-pyrochlore	sl-gl-cp-py-po-pyrargyrite	Ag-Pb-Zn-Nb-U	Skarn occurs at gneiss/ limestone contact. Sulphides restricted to skarn. Drill core over 1 m assayed: Ag - 85.7 g/t; Pb - 10.2%; Zn - 10.5%. Pyrochlore contains up to 8% Nb and is associated with sphalerite.	AR 11862, 7368, 4938
49	Van (Shalto, Raven, Mound)	93L/7W 093L 202	O		Eocene Nanika intrusions – plugs and porphyritic quartz monzonite	Early – Middle Jurassic Hazelton Group, Telkwa Formation – breccia, tuff, rhyolitic to basaltic flows	ep-gt-amph-cc	cp-py-mt-moly	Au-Cu-Ag	Skarn in hornfelsed basalt and limestone, cp-moly from limestone assayed: Au - 1.03 g/t; Ag - 61.71 g/t; Cu - 4.9%.	AR 15259, 10563; GEM 1986, p.354
50	Fire (Kaza)	93M/16W 093M 111	O		50 Ma. Kastburg intrusions – qtz-feldspar dykes. Amphibolite dykes (?)	Triassic – Jurassic Takla Group – volcanics, tuffaceous limestone, marble	ep-gt-tr-cc	bn-py-cp-sl-mt-po	Au-Ag-Cu-Zn	Skarn in amphibolite at dyke/limy horizon contacts. Assay over 4.0 m yielded: Au - 15.4 g/t; Ag - 12.7 g/t; Cu - 0.88%.	AR 4477, 12533; MMAR 1968, p.118
51	Soup	94D/8E 094D 105	O		Middle Cretaceous Hogem batholith – qtz. monz. stock and related dykes. Cretaceous calcalkaline to alkaline diorite stocks and sills	Triassic – Jurassic Takla Group – andesite, augite porphyry flows and dykes, pycl. Regional greenschist metamorphism	ep-act-gt	mt-cp-py	Au-Cu	Skarn follows bedding in volcanics with a large gossan zone on surface. Au occurs with cp in mt. Assays up to 23.7 g/t and 62.4 g/t Au reported.	AR 13315, 10743

(Appendix 1 continued)

Loc. No. in Fig. 3	Name(s)	NTS MINFILE	Type	Production (ore t)	Associated Intrusive Rocks	Host Rocks	Skarn Mineralogy	Opaque Mineralogy	Associated Metallic Elements	Comments	References
52	VIP (VIP 7, VIP 30, VIP 29)	94E/2W 094E 047 094E 048 094E 049	O		Omineca intrusions – qtz. monz./hb-bio granodiorite, cut by two leucocratic porph. monz.-syenite dykes	Pre-Triassic Asitka Group – limestone pendants. Triassic – Jurassic Takla Group – meta-siltstones, mb	gt-pyx-act-qtz-ep-bio	cp-py-mt-sl-spec	NR	Limestone breccia related to skarn(?). Copper-bearing gash veins in metasiltstone.	AR 7649, 5144; GEM 1974, p.311
52	Acapulco (Aca, Pul, Co, Amigo, Star, Sun)	94E/2W 094E 058	O		Early Jurassic Omineca intrusion – quartz monzonite. Hb-pyx gabbro	Permian Asitka Group or Triassic Takla Group – limestone	wo-pyx-cc-gt	mt-cp-bn-mal-gl-sl-po-py-tt	Au-Ag-Cu-Pb-Zn	Skarn at contact of limestone with quartz monzonite. Subvertical fractures possible fluid path. Massive mt skarn assayed: Au - 13.0 g/t; Ag - 82.3 g/t.	AR 11106
53	Pau (Perry Mason)	94E/6E 094E 072	O		Early Jurassic Toodoggone intrusions. Feldspar porphyry dyke	Permian Asitka Group – limestone and metasediments. Triassic Takla Group – volcanics	ep-act-gt	cp-mt-tt-gl-sl	Au-Ag-Cu-Pb-Zn	Skarn replaces Asitka and Takla Group rocks. Cp-mt associated with skarn; tt-gl-sl associated with silicification in Takla volcanics. Assays over 1 m reported: Au - 464.6 g/t; Ag - 7 360 g/t.	AR 14645, 11540
54	Moult (Rod, Hidden Lake, Hand C)	103A/9W 103A 002	O		Quartz diorite	Limestone and schist	gt	cp-py-bn-moly	Au-Ag-Cu-Mo	Mineralization at contact between quartz diorite and limestone/schist. Assays up to: Au - 1.4 g/t; Ag - 13.7 g/t; Cu - 1.6%.	GSC Memoir 372, p.99; MMAR 1966, p.54
55	Alpine (Apex, Star)	103B/12W 103B 008	O		Early Jurassic San Christoval batholith – quartz diorite	Triassic pendant of Kunga or Karmutsen Formation – limestone, volcanics	gt-ep-cc	mt-cp	Ag-Cu	Skarn at base of small pendant. Surface and drill indicated reserves of 163 000 tonnes @ 34% Fe; 0.90% Cu; 24.6 g/t Ag.	GSC Summary Report 1909, p.79; EMPR Bulletin 54, p.192; MMAR 1930, p.64
55	Tasu (Dela-Bluejay, Tasso, Warwick)	103C/16E 103C 003	P	(20 883 960 t) Au - 1 340 kg Ag - 50 394 kg Cu - 59 866 t Fe-12 253 786 t	Early Jurassic – Middle Cretaceous San Christoval batholith – hb-diorite/qtz. diorite. Porph. diorite lacolith	Late Triassic – Early Jurassic Karmutsen Formation – greenstone and Kunga Formation – limestone/arg.	chl-ep-act-tr-kspar-atp-qt-cc-gt	mt-py-po-cp-sl	Au-Cu-Ag-Zn	Ore zone consists of 4 stratiform magnetite bodies at top of Karmutsen Formation in volcanics. Sulphides are later than magnetite.	GSC Bulletin 172, p.81 - 82; MMAR 1968, p.70; GEM 1974, p.320 -321; GEM 1973, p.482 - 484

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Loc. No. In Fig. 3	Name(s)	NTS MINFILE	Type	Production (ore t)	Associated Intrusive Rocks	Host Rocks	Skarn Mineralogy	Opaque Mineralogy	Associated Metallic Elements	Comments	References
55	Ajax (Garnet, Ruby, King Neptune)	103C/16E 103C 004	O		Jurassic (?) San Christoval batholith – quartz diorite	Late Triassic Karmutsen Formation – greenstone and limestone	gt-ep-chl-qtz-amph	mt-py-cp-sl-moly	Au-Ag-Cu-Zn-Mo	Skarn and sulphides at ls./gnst. contacts. Py-cp-moly disseminated and fracture filling in qtz. diorite. Average assay of small mt. body reported as: Au - 6.9 g/t; Cu - 2.1%. Chip sample over 24 m reported: Au - 0.69 g/t; Ag - 89.1 g/t; Cu - 2.3%; Zn - 12.05%.	AR 10138, 5392; Sutherland Brown (1968) GEM 1974, p.321
56	Alder Island	103B/6W 103B 017	O		Late Cretaceous – Early Tertiary Burnaby batholith – quartz monzonite	Late Triassic Karmutsen Fm. – volc.; Kunga Formation – limestone; Yakoun Fm – volcanics; and Early Cretaceous Longarm Formation – ss	pyx-gt-act-zo	po-cp-moly-mt-Ni-allemontite	Au-Cu-Mo-Ni-As-Sb	Mineralization in mylonite zone. Soil geochemistry reports 5.5 g/t Au.	AR 8251; Sutherland Brown (1968)
57	East Copper Island (Elma Group, Red Raven, Skincuttle Entrance)	103B/6E 103B 022	P	(50 t) Ag - 715 g Cu - 7 133 kg	Burnaby batholith; Karmutsen Formation sills ?	Triassic – Jurassic Karmutsen Formation andesite sills and Kunga Formation – limestone	gt-ep-hb-cc-qtz	cp-bn-py-mt-tn-mal-ct	Au-Ag-Cu	Skarn follows contacts along sills and replaces volcanics. Mineralization occurs as disseminated cp in gt; as veinlets cross-cutting bedding and in qtz - cp veinlets filling block faults.	Sutherland Brown (1968); GSC Summary Report 1909, p.78
57	Lily mine	103B/6E 103B 028	P	(13 410 t) Au - 51 195 g Ag - 862 548 g Cu - 574 055 kg	Late Cretaceous – Early Tertiary Jedway stock(?)	Late Triassic – Early Jurassic Karmutsen Formation – gnst., ls. and Kunga Formation limestone	act-chl-gt-cc	mt-po-cp-py-sl	Au-Ag-Cu-Zn	Mineralization occurs in veinlike masses within altered and sheared greenstone.	AR 14818, 14189; Sutherland Brown (1968); MMAR 1925, p.447
57	Chrysanthemum (Rose)	103B/6E 103B 029	O		Late Cretaceous – Early Tertiary Collison Bay stock – porph. diorite	Late Triassic Karmutsen Formation – greenstone, limestone	gt-chl-ep-pyx	mt-po-cp-py	Au-Cu	Gently dipping magnetite lenses. Drill core assay reports 2.07 g/t Au over 1.5 m.	Sutherland Brown (1968); Falconbridge Ltd. company reports
57	Moresby Island	103B/6E 103B 036	O		Late Cretaceous – Early Tertiary Jedway stock	Late Triassic Karmutsen Formation – limestone	gt-ep-act	mt-cp	Cu-Ag	Skarn at contact of quartz diorite/gnst. Surface chip sampling assayed: Ag - 34 g/t; Cu - 1.1%.	Sutherland Brown (1968); GSC Summary Report 1909, p.77

(Appendix 1 continued)

Loc. No. in Fig. 3	Name(s)	NTS MINFILE	Type	Production (ore t)	Associated Intrusive Rocks	Host Rocks	Skarn Mineralogy	Opaque Mineralogy	Associated Metallic Elements	Comments	References
57	Morning (Lotus, Daylins, Maple Leaf, Cu, Roy's Showing, Ikeda, Collison Bay)	103B/6E 103B 039 through 103B 045 103B 047 103B 069 103B 070	P	(29 t) Au - 870 g Ag - 747 g Cu - 721 kg (from Cu claims)	Late Cretaceous – Early Tertiary Collison Bay stock – diorite and Carpenter stock – quartz monzonite	Late Triassic – Karmutsen Formation – limestone, basalt. Kunga Formation – limestone	gt-pyx-qtz	mt-py-cp-po-as-bn	Au-Cu-Ag	Mineralization following faults as dyke-like sulphide bodies and at intrusive contacts. Assays reported: over 55 m – Au - 0.7 g/t; Ag - 18.5 g/t; Cu - 0.37%. Over 2.6 m – Au - 1.2 g/t; Ag - 8.5 g/t; Cu 2.47%; Grab sample - Au; 4.55 g/t; Ag - 35.0 g/t; Cu - 5.88%.	AR 13102, 14189; Young and Uglow (1926); Sutherland Brown (1968); Falconbridge Ltd. company reports
58	Edd (Great West, Ban, Marble Bay)	103G/9W 103G 018	O		Coast plutonic complex – quartz monzonite/ diorite, granodiorite	Roof pendant of micaceous quartzite, limestone, schist, slate	ep-chl-gt	moly-cp-py-bn	Au-Mo-Cu-Ag	Skarn occurs at quartz diorite/limestone contact. Sulphides concentrated in skarn. Chip sample yielded: Au - 0.31 g/t; Ag - 10.2 g/t; Cu - 1.36%; MoS_2 - 0.02%.	GSC Paper 70 - 41
59	Bob (Bank, Banks Island)	103G/8E 103G 024	O		Cretaceous (?) Coast intrusion – Bob biotite-quartz diorite	Paleozoic (?) marble	gt-pyx-cc-qtz-chl-ep-amph	py-cp-po-as	Au-Ag-Cu	Limited skarn formation in marble near quartz diorite contact. Mineralization primarily in quartz- pyrite filled fracture zones cutting quartz diorite.	MMAR 1963, pp.21 - 23; Trader Resources Ltd. company reports; AR 14171, 12719
59	Discovery (Hepler Lake, Banks Island)	103G/8E 103G 025	O		Cretaceous (?) Coast intrusion – Kim biotite-quartz monzonite	Paleozoic (?) marble	gt-pyx-chl-qtz-cc	py-po-cp-mt	Au-Ag-Cu	Au occurs in quartz- pyrite vein subparallel with skarn/marble contact and in massive pyrrhotite replacement of marble.	AR 14171, 12719, 5720, 5022; Trader Resources Ltd. Company Reports
59	Quartz Hill (Ex, Island, Banks Island)	103G/8E 103G 031 103G 033 103G 035	O		Cretaceous (?) Coast intrusion – hornblende-biotite- quartz monzonite/ diorite	Paleozoic (?) metasediments – marble siltstone, limy argillite	gt-act	py-si-cp	Au-Ag-Cu-Zn-Pb	Au in qtz. stringers. Chip sample over 3.0 m assayed: Au - 1.54 g/t. Over 1.2 m: Au - 2.06 g/t; Zn - 0.37%; Cu - 1.73%. Grab sample assayed: Au - 3.4 g/t; Ag - 27.4 g/t; Zn - 2.0%; Pb - 0.71%.	AR 14171, 12719; GEM 1985, p.367
60	Bluebell (Ken, Copper Cliff)	103H/7W 103H 021	O		Coast plutonic complex – quartz diorite	Crystalline limestone, schist	pyx-gt-qtz-ep	cp-bn-chc-cv	Cu		GSC Paper 70 - 41; AR 3347; GSC Summary Report 1921A, p.39

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Loc. No. in Fig. 3	Name(s)	NTS MINFILE	Type	Production (ore t)	Associated Intrusive Rocks	Host Rocks	Skarn Mineralogy	Opaque Mineralogy	Associated Metallic Elements	Comments	References
60	Gribble Island (Empress, Ox)	103H/7W 103H 022	P	(35 t) Au - 31 g Ag - 1 306 g Cu - 372 kg	Coast plutonic complex – hornblende-biotite - quartz diorite	Marble and schist	gt-qtz-ep-pyx	bn-chc-cv	Au-Ag-Cu	Mineralization as streaks and disseminations. Sediments folded into plunging anticline. Sample over 5.2 m assayed: Au - tr.; Ag - 13.7 g/t; Cu - 1.02%.	GSC Paper 70 - 41; GSC Summary Report 1921A, p.39; GEM 1971, p.112
61	Bolton (Pink Rose)	103H/2E 103H 029	O		Butedale pluton – granodiorite	Pendant of altered limestone, and chl. schist	gt-ep	chc-bn	Au-Ag		GSC Summary Report 1921A, p.38; MMAR 1930, p.66
62	Lady Luck	103I/7E 103I 013	O		Mesozoic hb-diorite intruded by biotite-hb granodiorite stock and dykes. Skarn reported to be associated with gabbro stock	Paleozoic – limestone, quartzite, graphitic shale, argillite, limestone, and tuff	ep-gt-cc-chl-tr	mt-py-sl-cp-moly	Cu-Mo-Ag	Mineralization in breccia adjacent to pluton. Drill core assay over 1.5 m: Ag - 6.2 g/t; Cu - 0.87%; Mo - 0.043%. Grab sample assay: Ag - 21 g/t; Cu - 0.55%; Mo - 0.01%.	AR 3585, 4978
63	North Star (Avon, Lowrie)	103I/9E 103I 086	O		Coast plutonic complex – granodiorite stock	Triassic – Jurassic Hazelton Group – andesite, limestone	gt-ep-qtz-cc	cp-py-bn-chc	Au-Ag-Cu	Assay over 0.6 m reported: Au - 2.1 g/t; Ag - 1.4 g/t.	GSC Memoir 212, pp.15 - 16; GSC Summary Report 1925A, p.114
64	Blue Bell (Copper Queen, Surprise, Gazelle)	103I/8W 103I 131	O		Coast plutonic complex granodiorite	Carb.-Permian(?) – volcaniclastics, andesite/rhyolite tuff, limestone	ep-gt-cc-qtz	mt-cp-gl-sl-bn-py-po	Ag-Cu-Pb-Zn-Au	Skarn replaces limestone. Mineralization occurs as disseminations, clots, and in qtz. veins. Chip sample over 0.46 m: Au - tr; Ag - 223 g/t; Cu - 1%; Pb -7%; Zn - 11%.	GSC Summary Report 1926A, pp.42 - 43; AR 14076; GSC Memoir 205, p.5
65	Por (Etta)	103J/1W 103J 023 103J 027	O		Diorite stocks and dykes, granite, quartz diorite, gabbro	Late Paleozoic (?) – ls., qtzt., arg., tuff, gnst., qtz-cordierite hornfels. Metamorphism up to amphibolite grade	ep-gt-pyx	py-sl-cp-mt-po	Au-Ag-Cu-Zn	Mineralization at contact between granite/ hornfels. Surface sample assayed: Ag - 1.37 g/t; Zn - 8.0%; Cu - 0.11%.	AR 13051, 5027
66	Molly B (Mollie B, Oral M)	103P/13W 103P 085	P	(290 t) Au - 684 g Ag - 3 483 g Cu - 2 075 kg	Coast Range batholith	Jurassic Hazelton Group – tuffs, argillite, limestone	gt-ep-pyx-qtz-sch	moly-py-po-cp	Au-Ag-Cu-Mo-W		AR 10 004; GSC Memoir 175, p.132; Sutherland Brown (1968)

(Appendix 1 continued)

Loc. No. in Fig. 3	Name(s)	NTS MINFILE	Type	Production (ore t)	Associated Intrusive Rocks	Host Rocks	Skarn Mineralogy	Opaque Mineralogy	Associated Metallic Elements	Comments	References
66	Red Reef (Sky and Reef)	103P/13W 103P 094	O		Eocene Hyder stocks – qtz. monzonite	Jurassic Hazelton Group – volc., greenstone, tuff, sediments	gt-pyx-qtz-ep-bio	py-po-cp-gl-sl	Au-Cu-Pb-Zn	Skarn at contact between qtz. monzonite-seds. – volc. Au in qtz. veins with po-gl.	AR 14431, 13527, 10004; Sutherland Brown (1968)
67	Konkin Gold Zone	104B/9E 104B 171	O		K-spar altered quartz diorite-diorite	Jurassic Hazelton Group – dolomite, quartzite., tuff	cc-chl-pyx-gt-qtz	mt-cp-py-mal-az-spec-lim	Au	Trenches assayed (1) over 6.5 m averaged: 10.6 g/t Au; (2) over 2.4 m averaged 8.6 g/t Au. Drill core assayed over 4.7 m: averaged 11.0 g/t Au.	Press releases dated September 18, 1987; November 2, 1987 – Teuton Resources Corp.
68	Helena (Buttle, Laverdiere, Sprog)	104M/1E 104M 022	O		Post Early Jurassic – bio-hb grdr. Mult. phase intrusive event is suggested	Pre-Permian Yukon Group – dolo., ls., calc. siltstone, qtzt., schist, gneiss	serp-chl-ep-tc-tr-cc-pyx-gt-wo-qtz-sch	mt-cp-spec-tt-py-po-moly-cob-ery-bn-mal-vl	Au-Ag-Cu-Co-Mo-W	Endoskarn important (?). Silicification occurs with skarn. Up to 0.69 g/t Au and 10.29 g/t Ag reported.	AR 10181, 9162, 4995; GSC Summary Report 1910, pp.50, 55 - 56; GSC Memoir 37, pp.117 - 121
69	TP (TP - main, TP - central)	104M/10E 104M 048 104M 050	O		Quartz feldspar porphyry stock, sills, dykes	Mesozoic volcanics and Pre-Permian Yukon Group – gneiss, schist, marble	gt-pyx-amph-ep	mt-co-ery-as-cp-mal-gl	Au-Co-Ag-As-Bi	Skarn replaces gneiss and marble. Sulphides occur in fracture zone cutting mt skarn. Grab sample assayed: Au - 4.2 g/t; Ag - 33 g/t; Pb - 0.15%; Co - 1.7%; As - 2.3%; Bi - 0.32%. Trench samples range from: Au - 4.48 g/t over 3.95 m to 22.6 g/t over 4.85 m Co - 0.02% over 3.95 m to 3.91% over 3.55 m.	AR 11300; Souther (1971); Ettlinger and Ray (1988); Schroeter (1986); Mihalynuk *et al.* (1989a and b)
70	Contact (Telemac)	104P/5W 104P 004	P	(25 t) Ag - 10 451 g Cu - 25 kg Pb - 1 947 kg	Late Cretaceous Contact and Cassiar stocks	Early Cambrian Ingenika Group – marble, hornfels	cc-qtz-rd-gt-sc-pyx-act-sch	mangano mt-gl-sl-py-moly-po-as-cp-tt-al-native bismuth-bm-cs	Ag-Cu-Mo-Zn-Pb-W-Bi-Mn	Possible Ag-Bi-rich base metal veins distal to skarn mineralization on Kuhn (104P071) claims.	AR 10512, 9406; McDougall (1954)
71	Snow (Cobra, B Zone, Joem, Tibor, Haskins Mountain)	104P/6W 104P 020 104P 038 104P 058	O		Eocene Mount Haskins stock – granitic porphyry dykes, sills	Early Cambrian Atan Group – limestone, argillite, siltstone, chert	gt-pyx	po-sl-cp-gl-as-bm-bismuth	Ag-Pb-Zn-Cu-Mo-Bi-Sn	Skarn occurs at ls.-arg., ls.-slst., and intrusive contacts. Pyx occurs distal to intrusion. Drill core over 3.6 m assayed: Ag - 67.2 g/t; Zn - 9%; Pb - 4.5%; Sn approx. 0.1%.	AR 48, 5121; GSC Memoir 319, pp.116 - 117; Dick (1979)

(Appendix 1 continued)

Loc. No. In Fig. 3	Name(s)	NTS MINFILE	Type	Production (ore t)	Associated Intrusive Rocks	Host Rocks	Skarn Mineralogy	Opaque Mineralogy	Associated Metallic Elements	Comments	References
72	Maid of Erin (State of Montana)	114P/10E 114P 007 114P 008	P	(3 294 t) Au - 342 g Ag - 1 500 kg Cu - 246 037 kg	Oligocene Tkope River intrusions – granite, quartz diorite, diorite, gabbro. Quartz feldspar porphyry dykes and sills	Devonian – Late Triassic Rainy Hollow pendants – micaceous quartzite, marble, argillite, gneiss, schist	gt-ep-amph-wo-chl-serp-pyx-qtz-cc-mo-zo-id	cp-bn-py-sl-gl-mt-wt-chc	Au-Ag-Bi-Cu-Pb-Zn	Skarn forms along carbonate clastic-contacts and at qtz.-feld. porphyry contacts with seds. Grab sample assayed: Ag - 2 623 g/t; Cu - 45.9%; Au - 0.69 g/t; Bi - 0.92%.	AR 11835, 10847, 9989, 9978; EMPR Bulletin 25, pp.55 - 58; GSC Open File 926
73	Camp Creek (Klehini River NE)	114P/10E 114P 039 114P 040	O		Oligocene Tkope River intrusions – granitic	Devonian - Late Triassic sediments, greenstone, volcanics	ep-chl	cp-sl-gl	Ag-Cu-Zn	Cu mineralization in skarn. Three skarn samples ranged from Au - tr; Ag - 13.7 - 336.0 g/t; Cu - 0.62 - 14.3%.	GSC Open File 926
74	Red Mountain (Fair)	114P/11E 114P 070	O		Hornblende – quartz-feldspar-porphyry dykes	Paleozoic ? limestone, cherty argillite, quartzite. Late Triassic Kaskawulsh Group – cherty tuff, argillite, limestone	ep-pyx-gt-ser-bio-tr-qtz	gl-sl-cp-py-po-as	Ag-Cu-Zn-Pb-As	Three styles of mineralization: (1) barren po-py argillite; (2) Pb-Zn-Ag-Cu skarns; (3) As-base metal qtz. shear zones. Skarn assayed up to: Ag - 996 g/t; Cu - 6.16%; Zn - 5.6%; Pb - 27.6%.	AR 13260; GSC Paper 79, pp.1A - 17 - 20; EMPR Paper 1986-1, pp.194 - 195

TABLE ABBREVIATIONS

SKARN AND OPAQUE MINERALOGY

ab - albite
act - actinolite
al - alabandite
amph - amphibole
ap - apatite
as - arsenopyrite
atp - anthophyllite
ax - axinite
az - azurite
bio - biotite
bm - bismuthinite

bn - bornite
cb - carbonate
cc - calcite
chc - chalcocite
chl - chlorite
cp - chalcopyrite
cs - cosalite
ct - cuprite
cv - covellite
cz - clinozoisite
dolo - dolomite

em - electrum
ep - epidote
ery - erythrite
gl - galena
gt - garnet
hb - hornblende
hd - hedleyite
hm - hematite
id - idocrase
ilm - ilmenite
kspar - potassium feldspar

mal - malachite
mc - marcasite
ml - maldonite
mn - microcline
mo - monticellite
moly - molybdenite
mt - magnetite
ol - olivine
plag - plagioclase
po - pyrrhotite
prh - prehnite

py - pyrite
pyr - pyrolusite
pyx - pyroxene
qtz - quartz
rd - rhodonite
sb - stibnite
sc - scapolite
sch - scheelite
ser - sericite
serp - serpentine
sl - sphalerite

spec - specular hematite
sph - sphene
tn - tennantite
to - tourmaline
tt - tetrahedrite
tr - tremolite
vl - valleriite
wt - wittichenite
wo - wollastonite
zo - zoisite

HOST ROCKS

aggl - agglomerate
and - andesite

arg - argillite
bx - breccia

conglom - conglomerate
gnst - greenstone

ls - limestone
mb - marble
pycl - pyroclastic

qtzt - quartzite
slst - siltstone

ss - sandstone
volc - volcanic
vlcl - volcaniclastics

O - occurrence or prospect
P - producing mine or past producer

REFERENCES

AR - Unpublished Assessment Report
EMPR - B.C. Ministry of Energy, Mines and Petroleum Resources
GEM - B.C. Ministry of Energy, Mines and Petroleum Resources, Geology, Exploration and Mining in British Columbia
GSC - Geological Survey of Canada
MMAR - B.C. Minister of Mines Annual Report
NMI - National Mineral Inventory, Ottawa
NR - Not reported

APPENDIX 2
MAJOR ELEMENT GEOCHEMISTRY - UNALTERED HEDLEY INTRUSIONS

Lab No.	Field No.	SiO_2	TiO_2	Al_2O_3	Fe_2O_3**	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	CO_2*	FeO*	LOI	Sum*
30825	50.00	54.21	0.79	19.20	9.25	0.17	4.49	9.90	2.69	0.83	NA	0.48	7.19	1.68	103.21
30826	52.00	54.29	0.83	19.53	8.11	0.15	3.24	9.16	3.12	0.93	NA	0.35	6.29	1.25	100.61
30827	60.0A	56.81	0.60	17.50	7.03	0.12	3.81	7.98	3.03	1.64	NA	0.28	5.48	0.97	99.49
30828	61.00	60.45	0.46	17.12	5.72	0.12	2.55	6.41	3.48	1.67	NA	0.41	4.16	1.37	99.35
30829	62.00	54.08	0.68	18.35	8.77	0.17	4.03	9.25	2.91	1.11	NA	0.14	5.93	1.03	100.38
30830	63.00	62.71	0.36	18.24	3.31	0.07	1.94	6.71	3.68	2.03	NA	0.35	2.39	0.66	99.71
30831	64.00	52.94	0.65	19.89	7.93	0.15	4.04	10.15	3.40	1.24	NA	0.42	5.75	1.10	101.49
30832	65.00	59.48	0.53	17.86	6.41	0.11	2.51	6.66	3.28	2.00	NA	0.28	4.72	1.00	99.84
30833	66.00	53.27	0.72	19.02	8.75	0.16	3.93	9.12	3.10	1.35	NA	0.41	6.69	1.32	100.74
30834	67.00	50.82	0.65	20.24	8.39	0.17	4.18	10.30	2.90	0.75	NA	0.35	6.12	1.24	99.64
30835	68.00	59.46	0.51	17.99	5.83	0.13	2.88	7.24	3.72	2.01	NA	0.35	4.15	0.87	100.64
30836	69.00	54.27	0.64	19.33	7.66	0.17	3.27	9.19	3.20	1.55	NA	0.48	5.23	1.12	100.40
30837	70.00	49.13	0.80	20.18	9.07	0.16	5.09	11.46	2.55	1.17	NA	0.42	6.76	1.51	101.12
30838	71.00	55.92	0.58	18.41	7.27	0.14	3.13	8.14	3.22	1.66	NA	0.14	5.26	1.26	99.73
30839	72.00	54.85	0.65	18.72	8.08	0.15	3.54	8.73	3.06	1.65	NA	0.21	5.72	1.17	100.60
30840	73.A	57.68	0.67	18.60	7.91	0.15	3.10	8.23	3.22	1.80	NA	0.28	5.58	1.26	102.62
30843	60.0B	57.24	0.62	18.01	7.13	0.13	3.86	8.04	3.04	1.65	NA	0.29	5.36	0.96	100.68
30844	73.B	55.38	0.66	18.61	8.05	0.15	3.06	8.00	3.21	1.78	NA	0.29	6.15	1.15	100.05
31846	130.00	54.01	0.68	18.39	8.74	0.15	4.44	8.93	2.66	1.21	0.17	0.83	7.25	1.44	100.82
31847	131.00	54.60	0.66	18.79	8.32	0.13	4.18	8.14	2.81	1.53	0.18	0.42	7.18	1.25	100.59
31849	156.00	54.83	0.67	18.81	7.98	0.14	4.83	8.00	3.20	0.64	0.14	0.35	6.90	1.42	100.66
31850	157.00	55.56	0.66	18.71	7.53	0.16	4.16	7.13	3.28	1.37	0.17	0.49	5.62	1.82	100.55
31851	158.00	53.33	0.56	19.24	8.19	0.14	4.45	9.47	2.77	1.17	0.17	0.07	5.83	1.36	100.85
31852	159.00	55.61	0.61	18.38	7.35	0.12	3.69	8.12	2.91	1.00	0.15	0.14	5.97	1.35	99.29
31854	161.00	54.12	0.65	18.22	8.32	0.14	4.10	8.32	2.72	1.01	0.16	0.14	6.82	1.11	98.87
31855	162.00	53.36	0.68	18.57	7.31	0.12	4.23	8.32	2.77	1.10	0.16	0.07	4.94	2.69	99.31
31856	163.00	54.13	0.62	17.55	6.64	0.09	3.99	6.48	4.79	2.13	0.16	0.28	5.62	1.75	98.33
31857	164.00	56.38	0.58	18.37	6.29	0.10	3.41	7.10	4.06	1.01	0.17	0.07	4.34	1.28	98.75
31858	218.00	54.31	0.61	18.29	6.01	0.07	3.83	7.45	3.34	2.08	0.18	0.62	4.90	2.43	98.60

NA = not analysed.

*NOTE: CO_2 and FeO not included in Sum.

FeO determined by volumetric titration.

**Total iron.

APPENDIX 3

TRACE ELEMENT GEOCHEMISTRY - UNALTERED HEDLEY INTRUSIONS

Lab No.	Field No.	Au (ppb)	Ag	Cu	Pb	Zn	Co	Ni	Mo	Cr	Hg (ppb)	As	Sb	Ba	Sr	Bi	Rb	Y	Zr	U	Th
30825	50.00	1	0.1	12	<3	93	34	10	<3	<3	<25	7	<10.0	940	575	<3	5	12	48	<2	29
30826	52.00	8	0.1	7	4	82	30	7	<3	<25	<25	8	<10.0	962	614	<3	3	14	55	<2	23
30827	60.0A	6	NA	28	4	59	36	16	<3	58	25	<10	<10.0	1140	450	<3	35	13	61	<2	30
30828	61.00	1	0.2	16	9	65	35	7	<3	39	25	6	<10.0	1425	508	<3	33	13	74	<2	34
30829	62.00	1	0.1	30	3	71	37	4	<3	<25	<25	7	<10.0	862	546	<3	22	12	52	<2	25
30830	63.00	6	NA	4	5	25	36	4	<3	<25	<25	<10	10.0	1403	588	<3	25	10	60	3	31
30831	64.00	1	0.1	7	3	59	35	4	<3	<25	<25	7	<10.0	1307	810	<3	17	13	47	2	28
30832	65.00	5	0.1	5	6	50	32	2	<3	<25	30	5	<10.0	1300	333	<3	29	18	81	<2	23
30833	66.00	9	0.1	9	9	74	32	4	<3	<25	30	12	<10.0	918	494	<3	22	14	53	<2	32
30834	67.00	4	0.1	15	4	62	30	7	<3	<25	25	12	<10.0	606	653	<3	18	12	40	<2	23
30835	68.00	6	0.1	8	3	42	29	4	<3	<25	<25	4	15.0	1154	380	<3	27	14	68	<2	25
30836	69.00	1	NA	28	3	57	30	3	<3	<25	25	<10	<10.0	1232	520	<3	21	15	50	<2	19
30837	70.00	9	0.1	60	3	60	31	6	<3	42	50	17	<10.0	1068	466	<3	35	13	44	1	35
30338	71.00	12	0.1	8	3	51	31	4	<3	32	30	5	<10.0	<40	708	<3	39	12	66	<2	23
30839	72.00	20	0.1	11	<3	58	31	3	<3	<25	25	10	<10.0	1014	519	<3	26	12	56	<2	27
30840	73.A	5	NA	6	5	60	27	3	<3	<25	25	<10	<10.0	1273	484	<3	29	16	70	<2	27
30843	60.0B	6	NA	25	5	58	37	12	<3	64	40	<10	<10.0	1160	438	<3	41	10	64	<2	24
30844	73.B	10	NA	5	7	61	28	2	<3	<25	40	<10	<10.0	1200	494	<3	28	17	70	2	30
31846	130.00	2	0.3	33	17	79	37	13	<3	43	11	39	3.4	821	627	13	34	16	64	2	29
31847	131.00	1	0.3	26	10	79	37	4	<3	25	<10	29	2.3	1193	619	13	50	16	60	4	30
31849	156.00	1	0.1	22	23	93	41	25	<3	52	<10	98	2.5	756	841	8	14	11	53	2	25
31850	157.00	1	0.2	13	9	87	33	9	<3	31	<10	19	1.1	811	667	<5	32	14	59	1	22
31851	158.00	1	0.2	30	13	92	35	13	<3	34	28	12	<1.0	854	636	<5	28	13	51	<2	16
31852	159.00	1	0.1	12	12	71	32	8	<3	23	10	9	<1.0	652	654	<5	30	13	67	1	25
31854	161.00	1	0.3	22	14	58	37	11	<3	35	23	19	1.0	653	679	<5	23	13	60	<2	18
31855	162.00	1	0.6	46	13	58	38	11	5	28	13	172	1.1	1040	819	<5	32	14	59	3	23
31856	163.00	1	0.2	16	21	57	29	9	<3	23	21	19	1.7	1441	920	12	50	14	59	<2	21
31857	164.00	1	0.2	18	18	48	30	10	<3	19	12	20	<1.0	1022	837	11	30	12	63	<2	22
31858	218.00	1	0.7	73	15	76	29	8	<3	21	11	173	2.0	1520	676	9	50	14	59	<2	17

NA = not analysed.
All values in ppm unless stated in ppb.

APPENDIX 4

MAJOR ELEMENT GEOCHEMISTRY - SKARN-ALTERED (ENDOSKARN) HEDLEY INTRUSIONS

Lab No.	Field No.	SiO_2	TiO_2	Al_2O_3	Fe_2O_3**	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	CO_2*	FeO*	LOI	Sum*
30771	73.13	53.72	0.63	18.03	5.39	0.07	3.98	8.98	4.18	2.66	NA	0.64	3.85	1.99	99.63
30772	73.14	54.98	0.63	18.36	3.31	0.06	4.38	10.34	3.96	2.72	NA	0.28	2.53	1.04	99.78
30773	73.15	58.81	0.50	16.34	3.91	0.08	3.10	8.15	3.76	3.44	NA	0.63	3.12	0.88	98.97
30775	73.17	55.55	0.50	17.68	3.22	0.07	3.67	8.29	3.93	4.33	NA	0.21	2.43	1.07	98.31
30779	73.21	57.39	0.47	17.50	2.43	0.08	3.50	7.45	4.50	4.20	NA	0.70	2.14	1.25	98.77
30786	73.28	57.03	0.53	18.08	4.68	0.09	3.04	9.03	4.12	1.48	NA	0.77	4.13	1.43	99.51
30790	73.32	54.15	0.65	18.38	6.12	0.10	4.01	7.64	4.23	2.01	NA	0.91	4.50	1.90	99.19
30793	73.17	57.29	0.55	17.34	3.24	0.06	3.65	8.37	3.83	4.40	NA	0.21	0.24	1.08	99.81
30797	261.03	59.23	0.44	16.63	2.99	0.09	2.10	6.67	1.73	9.88	NA	0.21	2.57	0.59	100.35
30798	261.04	61.24	0.46	16.94	2.60	0.06	2.60	7.18	3.75	3.84	NA	0.36	2.14	0.70	99.37
30799	261.05	63.55	0.46	17.29	1.56	0.04	2.19	7.64	4.37	2.94	NA	0.14	1.36	0.65	100.69
30805	261.11	57.32	0.54	18.29	3.11	0.09	3.18	3.67	5.24	2.05	NA	0.48	2.63	1.01	99.50
30819	261.25	59.98	0.50	16.24	4.60	0.06	3.07	7.20	3.66	2.25	NA	1.03	3.97	1.32	98.86
30821	261.27	55.50	0.70	18.09	3.99	0.07	3.52	9.55	3.41	3.49	NA	0.72	3.36	1.42	99.74
30841	84.00	59.79	0.50	15.68	4.97	0.14	3.04	11.43	3.73	1.07	NA	0.21	3.83	0.45	100.80
30842	85.00	61.87	0.55	18.16	3.76	0.04	2.41	7.63	3.62	2.28	NA	0.22	2.82	0.65	100.97
31848	155.00	60.37	0.46	18.01	5.62	0.12	2.66	6.03	3.37	2.13	0.14	0.42	3.98	2.07	100.98
31853	160.00	60.47	0.43	18.34	4.46	0.07	2.29	6.03	4.51	0.96	0.14	0.62	3.48	1.37	99.07
31871	401.04	51.17	0.63	17.09	6.57	0.12	6.36	10.20	3.38	2.14	0.05	0.07	5.31	1.58	99.29
31879	401.12	47.99	1.02	18.15	8.97	0.11	4.70	9.72	2.70	2.43	0.27	0.14	7.77	2.26	98.32
31883	401.16	52.57	0.61	15.94	7.66	0.06	3.57	8.25	2.05	5.11	0.27	0.63	6.70	2.00	98.09
31888	401.21	51.18	0.65	17.96	6.69	0.09	4.35	8.54	3.87	2.12	0.15	0.14	6.01	2.01	97.61
31890	401.23	54.89	0.62	18.51	6.37	0.09	4.54	7.74	3.99	1.48	0.17	0.56	5.76	1.21	99.61
31891	401.24	54.58	0.63	18.61	7.66	0.11	4.49	7.52	3.11	1.36	0.17	0.21	6.29	1.22	99.46
31902	403.02	57.22	0.60	17.08	6.22	0.09	2.71	6.14	3.33	3.03	0.20	0.36	5.12	1.75	98.37

NA = not analysed.

* NOTE: CO_2 and FeO not included in Sum.

FeO determined by volumetric titration.

**Total iron.

APPENDIX 5

TRACE ELEMENT GEOCHEMISTRY - SKARN-ALTERED (ENDOSKARN) HEDLEY INTRUSIONS

Lab No.	Field No.	Au (ppb)	Ag	Cu	Pb	Zn	Co	Ni	Mo	Cr	Hg (ppb)	As	Sb	Ba	Sr	Bi	Rb	Y	Zr	U	Th
30771	73.13	5	0.7	326	8	54	31	14	<3	<25	75	59.0	<10.0	1073	926	<3	62	13	61	<2	10
30772	73.14	62	1.9	243	33	135	30	7	4	<25	<25	379.0	10.0	1275	1004	<3	82	11	59	<2	20
30773	73.15	1	0.7	267	8	88	33	12	<3	<2	30	73.0	<10.0	1480	676	<3	64	11	78	<2	16
30775	73.17	NA	NA	1400	17	122	26	24	<3	<25	135	83.0	<10.0	2410	943	<3	103	10	65	<2	19
30779	73.21	1	0.1	10	6	28	11	11	<3	<25	<25	10.0	<10.0	1383	804	<3	86	5	60	1	20
30786	73.28	5	0.7	228	50	75	41	12	<3	42	50	510.0	11.0	983	962	<3	35	8	55	1	12
30790	73.32	14	0.5	43	7	70	27	7	<3	29	30	50.0	30.0	1224	1112	<3	34	19	63	5	28
30793	73.17	NA	NA	1500	18	132	30	26	<3	<25	145	77.0	<10.0	2560	990	<3	107	12	65	2	25
30797	261.03	NA	NA	5	18	53	31	8	<3	<25	<25	649.0	<10.0	4700	850	<3	217	10	71	<2	18
30798	261.04	24	0.1	6	7	32	25	7	<3	<25	25	18.0	20.0	2050	729	<3	76	9	67	<2	19
30799	261.05	NA	NA	4	12	40	25	6	<3	<25	<25	<10.0	16.0	1700	816	<3	43	9	80	<2	19
30805	261.11	NA	NA	235	16	54	27	4	<3	47	<25	44.0	<10.0	847	804	<3	88	7	57	<2	29
30819	261.25	1	0.4	210	8	30	40	12	<3	51	70	280.0	<10.0	1652	803	<3	33	13	77	<2	24
30821	261.27	32	0.6	156	13	31	22	7	<3	26	30	79.0	<10.0	2200	1128	<3	71	13	67	3	21
30841	84.00	NA	NA	77	6	51	37	24	<3	<25	<25	<10.0	<15.0	610	460	<3	<50	NA	NA	NA	NA
30842	85.00	NA	NA	25	20	88	35	6	<3	<25	<25	<10.0	<10.0	1820	594	<3	37	17	95	3	27
31848	155.00	3	0.1	7	13	60	27	8	<3	18	<10	24.9	1.0	1348	825	8	51	9	71	<2	15
31853	160.00	2	0.3	8	13	53	28	10	<3	19	<10	7.5	1.0	944	809	5	25	10	65	2	24
31871	401.04	8	0.7	220	24	126	28	38	<3	105	<10	660.0	2.1	803	612	<5	76	15	55	2	19
31879	401.12	4	1.0	102	15	75	32	29	<3	59	<10	12.4	3.6	1544	605	<5	78	19	55	<2	26
31883	401.16	22	3.6	98	31	124	31	11	<3	28	<10	9.3	1.7	3203	642	<5	102	24	94	7	30
31888	401.21	12	2.2	490	31	147	25	11	3	33	<10	8.2	2.5	1520	868	<5	54	17	59	1	25
31890	401.23	24	0.6	43	14	59	27	12	<3	26	<10	44.4	2.1	941	688	5	1282	107	314	<2	487
31891	401.24	6	0.3	44	5	63	27	10	<3	33	<10	16.9	1.5	523	578	<5	34	15	63	2	33
31902	403.02	5	0.9	150	20	76	37	10	<3	14	<10	19.8	3.3	1505	579	<5	65	24	89	2	24

NA = not analysed.

All values in ppm unless stated in ppb.

Assays by Analytical Sciences Laboratory, Ministry of Energy, Mines and Petroleum Resources, Victoria, except Au and Ag by ACME Analytical Laboratories Ltd., Vancouver, courtesy of D. Brabec and Mascot Gold Mines Ltd.

APPENDIX 6

MAJOR ELEMENT OXIDE ANALYSES AND CIPW NORMATIVE MINERALOGIES OF INTRUSIONS ASSOCIATED WITH PME SKARNS

(XRF whole-rock analyses from B.C.G.S. Analytical Sciences Laboratory)

Sample	1	2	3	4	5	6	7	8	9	10	11
Major Oxides											
SiO_2	50.66	67.79	66.63	65.85	63.84	71.03	72.74	70.81	69.28	52.91	71.51
TiO_2	0.63	0.35	0.40	0.39	0.54	0.24	0.27	0.28	0.31	0.98	0.28
Al_2O_3	17.48	16.96	16.71	17.37	17.80	15.29	15.14	14.57	15.80	17.55	14.31
Fe_2O_3	8.79	3.25	3.47	3.26	4.57	1.07	2.11	2.21	2.23	8.35	2.49
MnO	0.17	0.06	0.07	0.07	0.09	0.00	0.06	0.06	0.05	0.15	0.05
MgO	5.24	0.91	1.02	1.01	1.36	0.30	0.67	0.64	0.82	3.90	0.77
CaO	8.41	4.04	4.39	4.63	5.16	2.30	2.77	2.73	3.14	8.22	1.90
Na_2O	1.95	4.28	4.28	4.44	4.32	3.43	3.56	3.61	3.79	3.32	2.90
K_2O	1.79	1.47	1.41	1.37	1.43	2.88	3.05	2.97	2.94	1.25	5.01
P_2O_5	0.23	0.11	0.12	0.13	0.18	0.06	0.07	0.08	0.09	0.22	0.07
LOI	4.59	0.42	0.70	0.49	0.45	3.22	0.45	1.67	0.46	1.46	0.53
Total	99.94	99.64	99.20	99.01	99.74	99.82	100.89	99.63	98.91	98.31	99.82
CIPW Norm											
Volatile Free											
Q	5.08	27.67	25.95	24.03	20.03	36.12	33.51	32.57	28.77	5.50	30.70
C	0.00	1.26	0.46	0.49	0.20	2.58	1.11	0.66	0.91	0.00	0.84
or	11.09	8.76	8.46	8.22	8.51	17.62	17.94	17.92	17.65	7.63	29.82
ab	17.30	36.49	36.76	38.12	36.80	30.04	29.98	31.17	32.56	29.00	24.71
an	35.31	19.48	21.31	22.45	24.60	11.41	13.23	13.29	15.23	30.26	9.03
di	5.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.45	0.00
hy	19.88	2.60	3.08	2.74	5.19	0.77	1.66	1.63	2.07	12.41	1.93
mt	3.24	2.70	2.80	2.78	2.98	0.00	0.40	0.64	0.49	3.71	1.42
il	1.25	0.67	0.77	0.75	1.03	0.00	0.51	0.54	0.60	1.92	0.54
hm	0.00	0.00	0.00	0.00	0.00	1.80	1.49	1.37	1.50	0.00	0.81
ap	0.56	0.26	0.28	0.31	0.42	0.14	0.16	0.19	0.21	0.53	0.16

(Appendix 6 continued)

Sample	12	13	14	15	16	17	18	19	20	21	22
Major Oxides											
SiO_2	69.64	72.50	46.42	64.61	64.13	57.75	62.28	45.71	49.51	68.76	48.30
TiO_2	0.34	0.16	0.78	0.39	0.47	0.70	0.56	3.56	2.42	0.41	1.05
Al_2O_3	15.19	13.39	17.15	15.22	15.70	17.39	16.53	15.93	15.21	15.69	17.07
Fe_2O_3	2.72	1.42	12.95	2.03	4.61	6.44	5.69	14.33	8.72	4.13	11.93
MnO	0.05	0.02	0.18	0.13	0.12	0.12	0.11	0.25	0.22	0.09	0.18
MgO	0.79	0.36	7.76	1.20	1.42	2.39	1.71	3.09	4.30	1.35	5.64
CaO	2.25	1.75	9.17	3.97	3.81	5.85	3.73	10.01	11.77	3.78	11.13
Na_2O	3.10	2.70	1.76	3.22	3.77	4.18	4.05	3.70	3.72	3.61	2.78
K_2O	5.01	5.13	1.38	4.45	3.99	3.31	3.83	0.55	0.66	1.92	1.32
P_2O_5	0.09	0.04	0.07	0.18	0.23	0.43	0.30	1.21	1.06	0.09	0.37
LOI	1.08	2.58	2.69	4.34	1.13	1.47	1.36	0.70	0.89	0.00	0.00
Total	100.26	100.25	100.31	99.74	99.38	100.03	100.15	99.04	98.48	99.83	99.77
CIPW Norm											
Volatile Free											
Q	26.95	33.81	0.00	21.05	17.35	5.63	13.13	0.44	2.47	29.92	0.00
C	0.80	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.02	0.00
or	29.85	31.04	8.35	27.56	24.00	19.85	22.91	3.30	4.00	11.37	7.82
ab	26.44	23.38	15.25	28.55	32.46	35.87	34.68	31.83	32.24	30.59	23.14
an	10.66	8.62	35.68	14.62	14.40	19.20	15.82	25.67	23.43	18.20	30.28
ne	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23
di	0.00	0.00	8.57	3.44	2.70	6.05	0.76	13.75	23.05	0.00	18.63
hy	1.98	0.92	13.07	1.54	4.50	7.39	7.55	6.90	1.29	4.95	0.00
ol	0.00	0.00	12.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.41
mt	1.74	0.00	3.39	0.00	2.91	3.24	3.02	7.46	5.82	2.77	3.71
il	0.65	0.00	1.52	0.57	0.91	1.35	1.08	6.88	4.71	0.78	2.00
hm	0.65	1.70	0.00	1.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ru	0.00	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ap	0.21	0.10	0.17	0.44	0.55	1.02	0.71	2.87	2.53	0.21	0.86

(Appendix 6 continued)

Sample	23	24	25	26	27	28	29	30	31	32	33
Major Oxides											
SiO_2	51.39	66.76	55.21	59.62	61.51	56.86	75.34	56.75	53.77	61.72	57.47
TiO_2	0.84	0.50	0.66	0.56	0.46	1.92	0.20	1.60	1.42	0.55	1.01
Al_2O_3	18.80	16.18	17.65	17.62	16.42	15.50	13.28	15.52	14.65	17.15	17.12
Fe_2O_3	8.55	4.91	7.46	4.39	4.61	11.04	2.85	11.25	11.94	6.76	8.80
MnO	0.15	0.10	0.16	0.17	0.07	0.27	0.04	0.26	0.23	0.14	0.15
MgO	4.20	1.62	2.32	2.01	1.43	3.09	0.04	3.04	4.33	0.70	3.30
CaO	11.39	4.32	6.94	7.02	4.39	5.78	1.00	5.78	7.59	3.15	6.81
Na_2O	3.12	3.74	3.49	4.40	3.73	3.59	4.07	4.02	3.64	5.30	2.98
K_2O	0.86	1.58	2.83	1.97	2.57	1.27	3.00	1.24	1.05	1.88	1.99
P_2O_5	0.46	0.12	0.33	0.30	0.19	0.53	0.01	0.34	0.43	0.10	0.18
LOI	0.00	0.00	0.79	1.98	4.66	0.00	0.00	0.00	1.28	1.18	0.00
Total	99.76	99.83	97.84	100.04	100.04	99.85	99.83	99.80	100.33	98.63	99.81
CIPW Norm											
Volatile Free											
Q	1.37	26.56	5.82	11.08	18.93	13.04	38.01	9.99	5.43	14.10	11.52
C	0.00	0.76	0.00	0.00	0.00	0.00	1.55	0.00	0.00	0.94	0.00
or	5.09	9.35	17.23	11.87	15.92	7.52	17.76	7.34	6.26	11.40	11.78
ab	26.46	31.69	30.42	37.96	33.08	30.41	34.49	34.07	31.09	46.01	25.26
an	34.85	20.68	24.88	22.97	21.48	22.47	4.90	20.70	20.74	15.37	27.53
ne	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
di	15.35	0.00	6.94	8.44	0.05	2.29	0.00	4.83	11.94	0.00	4.23
hy	10.21	6.56	8.87	2.64	5.94	13.68	0.34	13.94	15.65	7.37	13.09
ol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
mt	3.40	2.90	3.23	3.05	2.98	4.97	2.47	4.50	4.27	3.05	3.65
il	1.60	0.95	1.29	1.08	0.92	3.65	0.38	3.04	2.72	1.07	1.92
ap	1.07	0.28	0.79	0.71	0.46	1.24	0.02	0.79	1.01	0.24	0.42

Abbreviations:

Q = quartz, C = corundum, or = orthoclase, ab = albite, an = anorthite, di = diopside, hy = hyperstene, ol = olivine, mt = magnetite, il = ilmenite, hm = hematite, ru = rutile, ap = apatite, NA = not analysed.

Sample Key:

1 = Dividend-Lakeview area, Osoyoos batholith; 2-5 = Banks Island, Bob deposit; 6-10 = Banks Island, Discovery deposit; 11-14 = Oka claims, Iron Horse showing; 15-18 = Nanaimo Lakes area, Island intrusion; 19-20 = Merry Widow mine, Coast Copper stock; 21 = Texada Island, Little Billie stock; 22 = Texada Island, Florence-Security dyke; 23 = Texada Island, Cornell stock; 24 = Texada Island, Little Billie stock; 25-27 = Texada Island, Gillies stock; 28-32 = Zeballos batholith; 33 = Hiller deposit, porphyry sill.

APPENDIX 7
TRACE ELEMENT DATA FOR SOME PME SKARNS IN BRITISH COLUMBIA

Sample No.	Au (ppb)	Ag (ppm)	Cu (ppm)	Pb (ppm)	Zn (ppm)	Co (ppm)	Mo (ppm)	As (ppm)	Bi (ppm)
1	<20.0	<0.5	7	11	118	4	<10	10	<10
2	4200.0	33.0	35	1500	126	17000	<10	23000	32000
3	25000.0	1.0	700	5	121	162	<10	6	150
4	<20.0	<0.5	21	6	120	22	<10	2	<10
5	<20.0	<0.5	9	3	85	4	<10	<10	<10
6	103000.0	3.0	2600	10	42	137	<10	20	24
7	300.0	4.0	2600	12	38	93	<10	3	<3
8	34000.0	64.0	237	1500	4100	68	<10	16000	69
9	67.0	3.0	276	34	267	22	<10	50	<3
10	17200.0	13.0	8100	12	312	575	30	445000	150
11	615.0	7.0	1210	5	43	34	25	180	9
12	19100.0	<0.5	12	16	92	5	20	20	<3
13	440.0	5.0	7500	26	53	53	20	84	23
14	<20.0	<0.5	33	13	103	20	<10	20	<3
15	4000.0	6.0	10000	13	730	112	<10	240	21
16	25.0	10.0	2100	14	572	13	<10	40	<3
17	120.0	24.0	5600	17	668	7	<10	31	<3
18	70.0	3.0	3600	25	238	191	<10	88	<10
19	<20.0	<0.5	24	9	70	3	<10	6	<10
20	<20.0	<0.5	8	36	45	6	<10	<1	<10
21	<20.0	<0.5	74	6	105	9	15	2	<10
22	180.0	54.0	32000	5	1100	360	<10	168	<3
23	<20.0	<0.5	23	4	263	<3	<10	74	<10
24	<20.0	1.0	80	5	67	16	<10	40	<3
25	<20.0	<0.5	445	4	287	7	<10	8	<10
26	20.0	<0.5	7	3	91	6	<10	9	<10
27	730.0	3.0	780	83	573	6	10	132	54
28	<20.0	0.7	77	10	37	<3	20	1	<10
29	370.0	54.0	26000	15	850	177	>10	120	<5
30	<20.0	<0.5	78	7	58	8	10	2	<10
31	<20.0	<0.5	18	7	48	5	<10	1	<10
32	110.0	3.0	620	140	1600	19	<10	168	23
33	590.0	4.0	5000	18	117	53	<10	120	3
34	40.0	<0.5	199	<5	93	34	<10	9	9
35	<20.0	<0.5	108	3	45	6	<10	7	<10
36	750.0	9.0	9800	<5	108	32	<10	102	9
37	170.0	3.0	3900	<5	160	53	<10	13	6
38	370.0	7.0	11000	11	540	71	<10	90	<3
39	4500.0	64.0	72000	5	1500	610	<10	120	<3
40	<20.0	0.5	50	11	87	42	<10	45	<3
41	50.0	<0.5	91	46	32	1500	10	1600	<10
42	32000.0	200.0	172000	7	29000	1600	<10	2000	6
43	<20.0	<0.5	30	8	118	16	<20	4	<10
44	1100.0	22.0	13000	39	39	2700	<20	107000	3
45	<20.0	<0.5	7	31	23	36	<20	<1	<10
46	<20.0	<0.5	22	4	58	13	<10	3	<10
47	6500.0	42.0	193000	6	210	250	22	78	<3

(Appendix 7 continued)

48	260.0	5.0	12000	7	48	420	<10	45	<3
49	240.0	5.0	9800	12	148	24	<10	66	<3
50	21000.0	0.7	590	22	33	43	<10	60	1400
51	7200.0	2.0	2200	<5	38	1600	10	151000	30
52	1100.0	<0.5	63	3	44	4	<10	29	<10
53	43000.0	1.0	2100	80	44	260	<10	480	1200
54	70.0	<0.5	30	18	126	8	<10	33	<10
55	2600.0	3.0	9800	11	120	115	<10	120	10
56	<20.0	0.6	11	10	9	<3	<10	<1	<10
57	<20.0	<0.5	50	9	86	20	<10	20	<10
58	2100.0	22.0	30000	<5	239	600	<10	84	8
59	<20.0	<0.5	7	8	10	<3	10	14	<10
60	<20.0	<0.5	7	15	42	<3	248	4	<10
61	1500.0	107.0	133000	33	2000	500	<10	108	32
62	20.0	0.6	16	17	52	7	104	5	<10
63	50.0	0.5	141	4	64	12	<10	5	<10
64	20.0	2.0	11	6	8	<3	<10	<1	<10
65	30.0	0.5	7	6	8	<3	<10	21	<10
66	30.0	2.0	1200	4	64	48	123	23	<3
67	<20.0	<0.5	55	6	56	4	<10	29	<10
68	99.0	<0.5	174	14	80	45	<10	250	10
69	950.0	147.0	133000	50	3100	680	<10	525	<5
70	80.0	1.0	208	6	23	3	<10	300	<3
71	10000.0	100.0	34000	180	154	8	<10	824	<3
72	480.0	3.0	3100	8	16	10	<10	153	<3
73	150.0	6.0	22000	14	90	23	147	240	<10
74	<20.0	<0.5	34	6	33	5	<10	29	<10
75	<20.0	<0.5	1300	22	55	4	<10	318	<10
76	1000.0	3.0	8400	26	80	28	<10	318	<10

Sample Descriptions:

1. TP - sulphide-poor garnet-pyroxene-amphibole skarn replacing feldspathic gneiss.
2. TP - pyroxene-cobaltite-erythrite skarn with oxidized arsenopyrite and 3-5% cobaltite.
3. Beano - dark green fibrous amphibole skarn with 5-6% pyrrhotite.
4. Zeballos - unaltered Zeballos batholith. Medium-grained hornblende diorite.
5. Zeballos - unaltered Zeballos batholith. Granodioritic phase with 15% hornblende and lesser amounts of biotite phenocrysts.
6. Banks Island, Discovery deposit - massive pyrrhotite skarn replacing limestone.
7. Banks Island, Discovery deposit - brecciated pyroxene skarn replacing limestone. 7-8% pyrrhotite as both disseminations and breccia matrix. Minor pyrite-chalcopyrite.
8. Banks Island, Discovery deposit - quartz-pyrite vein at exoskarn-marble contact. Approximately 15% pyrite partially oxidized and replaced by quartz-calcite.
9. Banks Island, Discovery deposit - pyroxene-actinolite skarn at marble-granodiorite contact. Remnant marble and intrusive fragments. 0.5-1% pyrite and minor pyrrhotite.
10. Oka, Iron Horse showing - massive arsenopyrite-pyrite-chalcopyrite skarn replacing limestone.
11. Oka, Iron Horse showing - gossan with remnant pyrite-chalcopyrite. Limestone protolith(?).
12. Oka, Iron Horse showing - sulphide-poor garnet-pyroxene skarn. Limestone protolith.
13. Oka, Iron Horse showing - pyritic gossan with trace chalcopyrite. Limestone protolith.
14. Oka, Iron Horse showing -Sulphide poor quartz-garnet-pyroxene-skarn vein.
15. Oka, Iron Horse showing - massive pyroxene-garnet-pyrite skarn crosscut by white zeolite(?) veins.
16. Oka, Cap showing - fine-grained pyroxene hornfels. Carbonate and minor disseminated pyrite-pyrrhotite.
17. Oka, Cap showing - pyroxene hornfels with clots of coarse calcite and quartz. 3-5% disseminated pyrrhotite-chalcopyrite.
18. Nanaimo Lakes - epidote-garnet endoskarn. Garnet stockwork cuts remnant quartz monzonite fragments. 0.5-1% pyrite-chalcopyrite.

(Appendix 7 continued)

19. Nanaimo Lakes - garnet-wollastonite skarn, minor pyroxene-quartz-tremolite. Limestone protolith. Trace pyrite.
20. Nanaimo Lakes - fine-grained quartz monzonite. Minor epidote-albite alteration of potassium feldspar. Limonite staining.
21. Nanaimo Lakes - Sicker Group massive crystal tuff. Minor patchy biotite and pyroxene hornfels. 0.5% pyrite disseminated in hornfelsed areas.
22. Nanaimo Lakes - banded garnet-pyroxene-amphibole skarn replacing Sicker Group tuff. Fibrous magnetite after hematite.
23. Nanaimo Lakes - massive granular garnet skarn replacing tuff. Intermixed yellow and brown garnet, minor pyroxene and amphibole cut by brown garnet veinlets. Sulphide poor.
24. Nanaimo Lakes - garnet-amphibole skarn breccia. Matrix of cream calcite, euhedral brown garnet and bladed amphibole contains fragments of yellow garnet skarn. Hematite replaces matrix and garnet skarn. Minor pyrite-chalcopyrite-magnetite.
25. Nanaimo Lakes - massive dark brown garnet skarn replacing crystal tuff. Sulphide poor.
26. Nanaimo Lakes - hematite-garnet breccia. Hematite pseudomorphs after zoned garnet with carbonate clasts in hematite-calcite matrix.
27. Nanaimo Lakes - massive hematite with finely disseminated quartz in Sicker Group at unconformity with Nanaimo Group conglomerate.
28. Nanaimo Lakes - massive grey crinoidal limestone of the Buttle Lake Formation.
29. Nanaimo Lakes - massive garnet-amphibole-epidote skarn with 0.5-1% disseminated chalcopyrite and pyrite.
30. Nanaimo Lakes - pinkish grey, medium-grained equigranular quartz monzonite with 15% hornblende, 30% quartz, 55% potassium and plagioclase feldspar and trace epidote.
31. Nanaimo Lakes - similar to Sample No. 30 but slightly more mafic. 20% hornblende, 2-3% biotite, 20% plagioclase phenocrysts, 55% quartz, potassium and plagioclase feldspar in matrix.
32. Nanaimo Lakes, Villalta claims - massive hematite replacement of breccia with some visible bedding and remnant clasts.
33. Benson Lake, Kingfisher mine - massive brown garnet endoskarn at marble contact. <1% disseminated chalcopyrite and pyrite. Possible replacement of greenstone dyke.
34. Benson Lake, Kingfisher mine - massive magnetite with clots of megacrystal calcite up to 1 m long. Minor chlorite and trace chalcopyrite.
35. Benson Lake, Kingfisher mine - greenstone dyke fragment in marble, partially replaced by brown garnet-epidote-pyroxene skarn.
36. Benson Lake, Merry Widow mine - banded gossan in marble. Malachite-azurite staining.
37. Benson Lake, Merry Widow mine - massive magnetite and megacrystic calcite replacing marble. Minor euhedral amber garnet, <0.5% chalcopyrite and pyrite.
38. Benson Lake, Merry Widow mine - garnet-epidote-amphibole skarn replacing marble. 0.5% pyrite and chalcopyrite.
39. Benson Lake, Merry Widow mine - massive magnetite with up to 20% chalcopyrite replacing marble at skarn front.
40. Benson Lake, Merry Widow mine - massive magnetite-calcite as in Sample No. 39, but no chalcopyrite present.
41. Benson Lake, Merry Widow mine - epidote-K feldspar-garnet endoskarn replacing andesite. Minor erythrite.
42. Benson Lake, Merry Widow mine - gossanous cap on massive magnetite-chalcopyrite skarn. Remnant magnetite-chalcopyrite and coarse calcite.
43. Benson Lake, Merry Widow mine, Coast Copper stock - medium-grained equigranular diorite/gabbro with 3-5% disseminated ilmenite and magnetite.
44. Benson Lake, Merry Widow mine - gossanous massive sulphide and magnetite skarn with remnant arsenopyrite-chalcopyrite-pyrite.
45. Benson Lake, Merry Widow mine - garnet-epidote endoskarn. Remnant diorite cut by red-brown garnet-epidote-K feldspar veins with irregular clots of magnetite.
46. Benson Lake, Merry Widow mine, Coast Copper stock - coarse gabbroic phase. Clinopyroxene crystals in plagioclase matrix and 2% euhedral ilmenite.
47. Benson Lake, Old Sport mine dump - massive chalcopyrite with up to 20% disseminated magnetite and minor garnet.
48. Benson Lake, Old Sport mine dump - massive pyrrhotite with up to 5% chalcopyrite.
49. Benson Lake, Old Sport mine dump - massive dark brown-black garnet skarn with trace amphibole. 0.5-1% chalcopyrite and <0.5% magnetite.
50. Dividend-Lakeview - sheared andesitic volcanics with 3-5% disseminated pyrite and minor magnetite; lies adjacent to quartz-epidote-actinolite skarn.
51. Dividend-Lakeview - massive arsenopyrite-pyrrhotite-pyrite skarn replacing sheared andesite (represented by Sample No. 50). Cut by coarse white calcite veins.
52. Dividend-Lakeview - pale tan garnet-epidote-calcite skarn with trace pyrite, cut by dark brown garnet-calcite veins. Replacing chloritic andesite.
53. Dividend-Lakeview - banded pyrite-magnetite replacing light green silicified marble.
54. Dividend-Lakeview - medium grey, fine to medium-grained mafic sill. Euhedral, hornblende phenocrysts, <1 mm in length, in light grey plagioclase matrix. 0.5% disseminated pyrite.
55. Dividend-Lakeview - disseminated sulphides in dark green, fine-grained garnet-amphibole skarn. 5-7% pyrrhotite and pyrite.

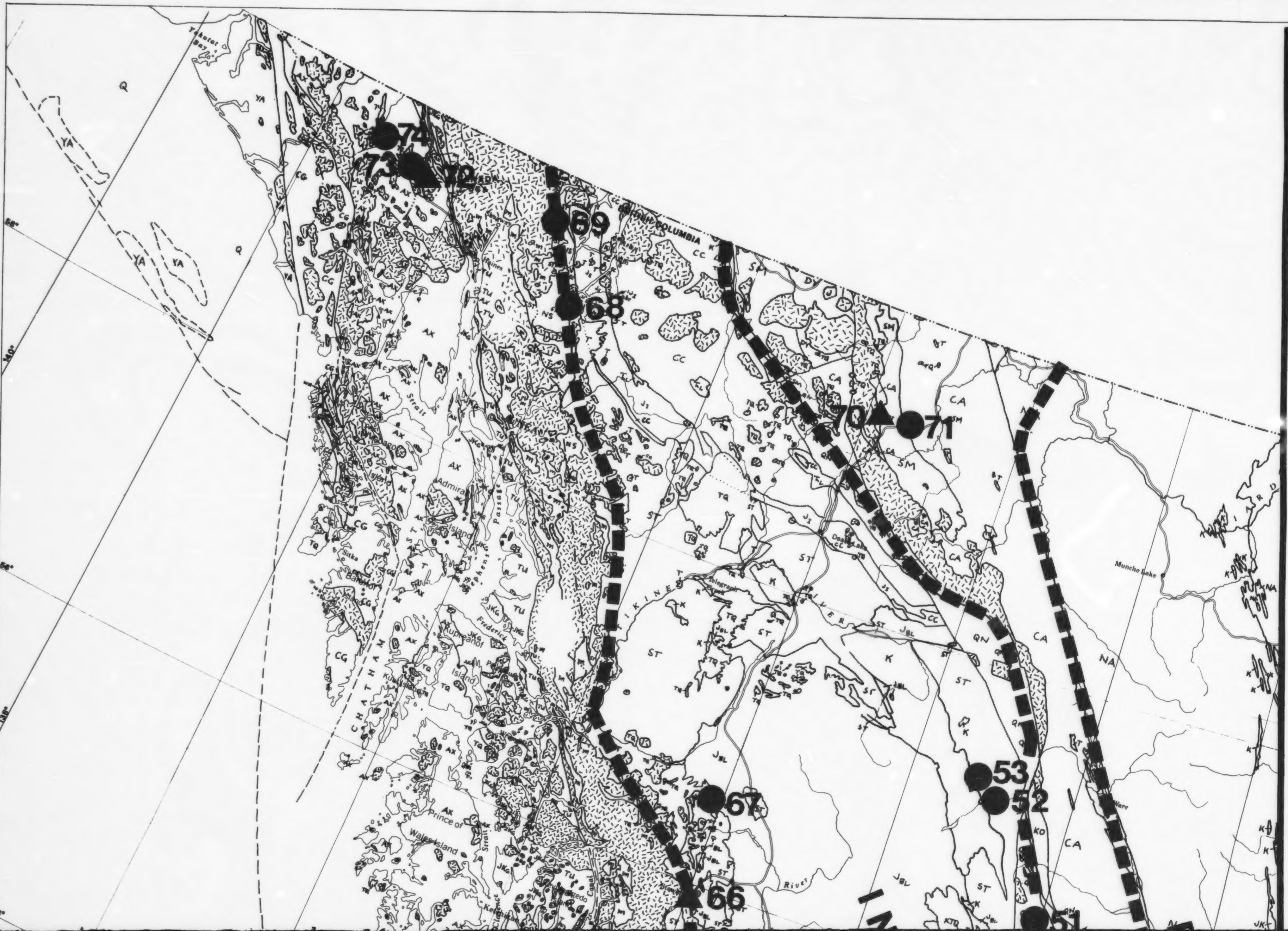
(Appendix 7 continued)

56. Dividend-Lakeview - light greenish grey, medium-grained marble. Main protolith to sulphide mineralization.
57. Dividend-Lakeview - approximately 500 m from main workings, Osoyoos batholith. Epidote-chlorite altered, fine to medium-grained quartz diorite.
58. Texada Island, Prescott mine - magnetite skarn with 60% magnetite, 35% quartz and calcite, 5% chalcopyrite, and pyrite, trace cobaltite. Limestone protolith.
59. Texada Island, Prescott mine - white, medium to coarse-grained marble with minor limonite and malachite staining.
60. Texada Island, Prescott mine - massive medium-grained epidote-amphibole-calcite skarn replacing marble.
61. Texada Island, Prescott mine - chalcopyrite stockwork in fractured coarse-grained marble. Up to 10% chalcopyrite, minor magnetite, trace pyrite.
62. Texada Island, Prescott mine - endoskarn in Gillies quartz monzodiorite stock. Veinlets of epidote with white albite selvages cutting medium-grained equigranular hornblende, plagioclase, potassium feldspar and quartz.
63. Texada Island, Lake mine - banded, sulphide-poor epidote-garnet-pyroxene-magnetite skarn replacing volcanics. Dark red garnet rims the magnetite bands.
64. Texada Island, Lake mine - White to light grey fine-grained recrystallized Marble Bay limestone. Sulphide poor.
65. Texada Island, Ideal Cement Co. quarry - "whiterock", white medium-grained marble. Sulphide poor.
66. Texada Island, Paxton mine - endoskarn in Gillies quartz monzodiorite stock. Epidote-garnet-pyroxene with 1-2% pyrite. Remnant igneous texture.
67. Texada Island, Paxton mine - altered Gillies quartz monzodiorite stock. Silicified matrix and epidote replacement of hornblende and plagioclase.
68. Texada Island, Paxton mine - altered volcanics. 1-2% pyrite and pyrrhotite in silicified basalt.
69. Texada Island, Paxton mine - banded sulphide skarn. 35% chalcopyrite-pyrrhotite-magnetite-pyrite in chlorite and amphibole skarn cut by calcite veinlets.
70. Greenwood camp, Phoenix mine - massive garnet-epidote skarn with 1% disseminated euhedral pyrite, cut by calcite-hematite stockwork.
71. Greenwood camp, Phoenix mine - stockwork sulphides in coarse white calcite, fine-grained chlorite and brown garnet skarn. Up to 20% chalcopyrite and pyrite.
72. Greenwood camp, Phoenix mine - specularite-chalcopyrite-calcite vein crosscutting fine-grained epidote-garnet skarn. Sharpstone conglomerate host. 2% chalcopyrite occurring in vein and disseminated in skarn.
73. Greenwood camp, Oro Denoro mine - massive amber-coloured garnet skarn replaced by chlorite, amphibole and sulphides. 1-2% chalcopyrite and minor pyrite.
74. Greenwood camp, Oro Denoro mine - endoskarn in Nelson batholith. Epidote-hematite alteration of mafics and minor silicification of quartz diorite matrix.
75. Greenwood camp, Oro Denoro mine - endoskarn in Nelson batholith. Massive reddish brown garnet, epidote and minor chalcopyrite replacing quartz diorite.
76. Greenwood camp, Motherlode mine - banded garnet-epidote-amphibole skarn replacing Brooklyn limestone. Minor black, 1-3 mm euhedral garnets in calcite-filled cavities appear to be later than banded brown garnet. 0.5% chalcopyrite and up to 1% pyrite disseminated in skarn.

ANALYTICAL METHODS AND DETECTION LEVELS FOR TRACE ELEMENTS ANALYSED IN THE 76 SAMPLES LISTED ABOVE

(Analyses completed at the EMPR Analytical Sciences Laboratory)

Element	Method	Detection Limit	
Au	Standard fire assay - graphite furnace/AAS finish	20	ppb
Ag	Mixed acid digestion/AAS	0.5	ppm
Cu	Mixed acid digestion/AAS	10	ppm
Pb	Mixed acid digestion/AAS	5	ppm
Zn	Mixed acid digestion/AAS	5	ppm
Co	Mixed acid digestion/AAS	3	ppm
Mo	Mixed acid digestion/AAS	10	ppm
As	Mixed acid digestion/AAS	3-10	ppm



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Prince of Wales Island
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Muncho Lake
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54°
138°
140°

Province of British Columb
Ministry of Energy, Mines and Petroleu
GEOLOGICAL SURVEY BRANCH

FIGURE 3

THE DISTRIBUTION PRECIOUS METAL ENRIC SKARNS IN BRITISH CO

To accompany Paper 1989-3
By A.D. ETTLINGER AND G.E. R

Plotted on the Geological Survey of
TERRANE MAP OF THE CANADIAN CO
Compiled by J.O. Wheeler, A.J. Brookfield, H. Gabr
H.W. Tipper and G.J. Woodswor
(In Preparation)

0 100 k
Scale

LEGEND

MIOGEOCLINE:

CRATON

NA	Ancestral North America

TERRANES:

NORTH AMERICAN BASEMENT?

MO	Monashee	
	MO?	Monashee - inferred

DISPLACED CONTINENTAL MARGIN

AA	Arctic Alaska	
CA	Cassiar	
	SUBTERRANE	
	CA_C	Cariboo
NS	Nisling	
PC	Porcupine	

PERICRATONIC

KO	Kootenay	
	SUBTERRANES	
	KO?	Kootenay - inferred
	KO_B	Barkerville
	KO_N	Nisutlin
PG	Pelly Gneiss	

ACCRETED TERRANES

INTERMONTANE SUPERTERRANE

SM	Slide Mountain	
DY	Dorsey	
QN	Quesnellia	
	SUBTERRANES	
	QN_H	Harper Ranch
	QN_O	Okanagan
CC	Cache Creek	
ST	Stikinia	
WM	Windy McKinley	

ACCRETED TERRANE

TERRANES OF

TU	Taku
CD	Cadwallader
MT	Methow
BR	Bridge River
HA	Harrison
CK	Chilliwack
SH	Shuksan

INSULAR SUPE

AX	Alexander
WR	Wrangellia

OUTER TERRA

CG	Chugach
YA	Yakutat
PR	Pacific Rim
CR	Crescent
OC	Olympic Core
OZ	Ozette
HO	Hoh

ROCKS EXCLUDED TERRANE CLASSI

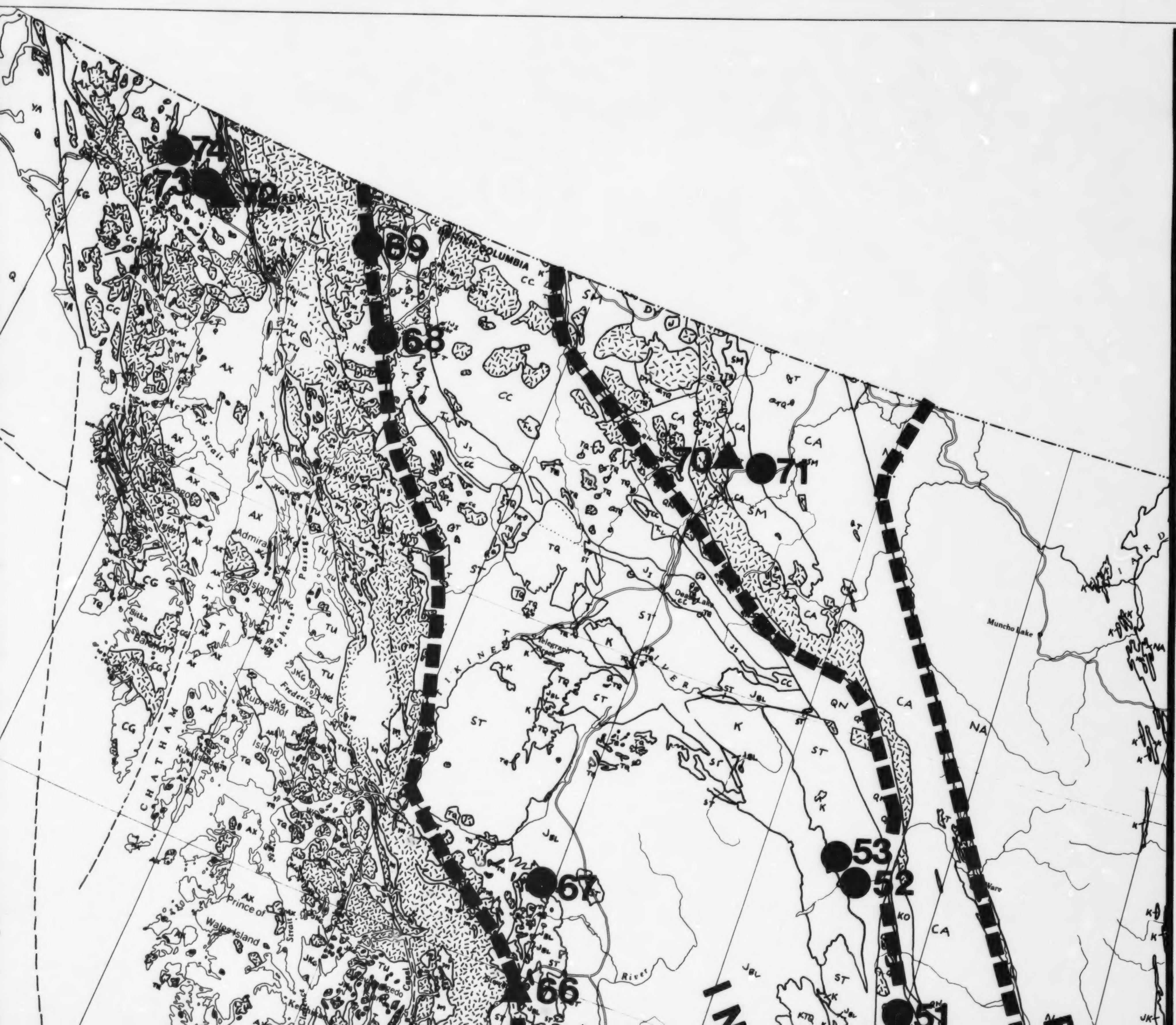
METAMORPHIC ASSE

m	undivided metam

POST-TERRANE ACCR

TR_L	Lewes River (on
J_{BL}	Bowser Lake (o
J_I	Inklin (on Cache
J_T	Takwahoni (on C
JK_G	Gambier (in Coa

POST-TERRANE ACCR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JBL
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STIKINE RIVER
Muncho Lake
CHATHAM STRAIT
Admiralty Island
Kupreanof
Frederick
Prince of Wales Island
Sitka
River

Province of British Columbia
Ministry of Energy, Mines and Petroleum Resources
GEOLOGICAL SURVEY BRANCH

FIGURE 3

THE DISTRIBUTION OF PRECIOUS METAL ENRICHED (PME) SKARNS IN BRITISH COLUMBIA

To accompany Paper 1989-3
By A.D. ETTLINGER AND G.E. RAY

Plotted on the Geological Survey of Canada
TERRANE MAP OF THE CANADIAN CORDILLERA
Compiled by J.O. Wheeler, A.J. Brookfield, H. Gabrielse, J.W.H. Monger,
H.W. Tipper and G.J. Woodsworth
(In Preparation)

0 100 km
Scale

LEGEND

MIOGEOCLINE:

CRATON

NA	Ancestral North America

TERRANES:

NORTH AMERICAN BASEMENT?

MO	Monashee	
	MO?	Monashee - inferred

DISPLACED CONTINENTAL MARGIN

AA	Arctic Alaska	
CA	Cassiar	
	SUBTERRANE	
	CA_C	Cariboo
NS	Nisling	
PC	Porcupine	

PERICRATONIC

KO	Kootenay	
	SUBTERRANES	
	KO?	Kootenay - inferred
	KO_B	Barkerville
	KO_N	Nisutlin
PG	Pelly Gneiss	

ACCRETED TERRANES

INTERMONTANE SUPERTERRANE

SM	Slide Mountain	
DY	Dorsey	
QN	Quesnellia	
	SUBTERRANES	
	QN_H	Harper Ranch
	QN_O	Okanagan
CC	Cache Creek	
ST	Stikinia	
WM	Windy McKinley	

ACCRETED TERRANES *(continued)*

TERRANES OF THE COAST BELT

TU	Taku
CD	Cadwallader
MT	Methow
BR	Bridge River
HA	Harrison
CK	Chilliwack
SH	Shuksan

INSULAR SUPERTERRANE

AX	Alexander
WR	Wrangellia

OUTER TERRANES

CG	Chugach
YA	Yakutat
PR	Pacific Rim
CR	Crescent
OC	Olympic Core
OZ	Ozette
HO	Hoh

ROCKS EXCLUDED FROM TERRANE CLASSIFICATION

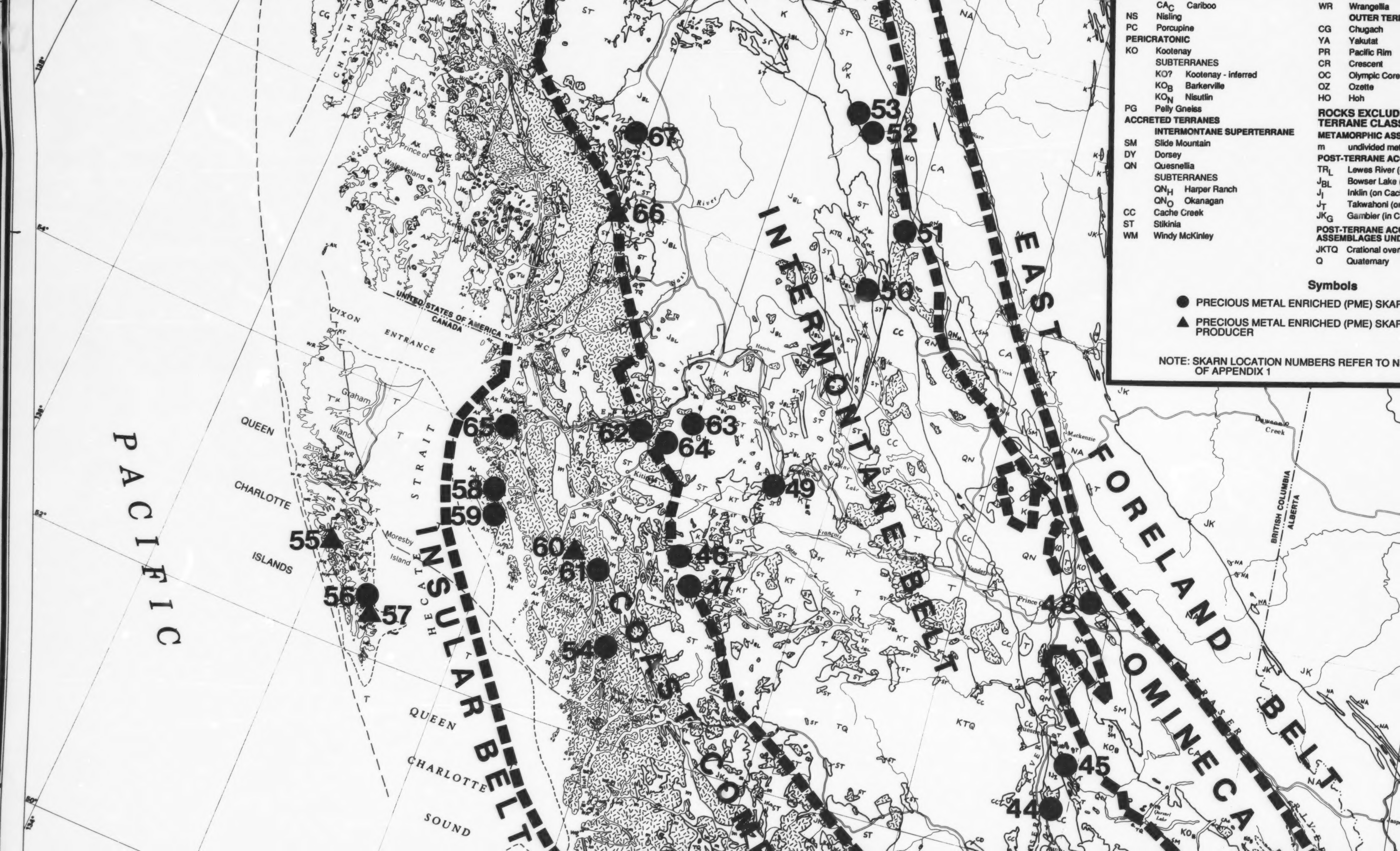
METAMORPHIC ASSEMBLAGES

m	undivided metamorphic assemblages

POST-TERRANE ACCRETION OVERLAP ASSEMBLAGES

TR_L	Lewes River (on Cache Creek terrane)
J_{BL}	Bowser Lake (on Stikinia)
J_I	Inklin (on Cache Creek terrane)
J_T	Takwahoni (on Cache Creek terrane)
JK_G	Gambier (in Coast Belt)

POST-TERRANE ACCRETION OVERLAP ASSEMBLAGES UNDIFFERENTIATED ON MAP


CA$_C$ Cariboo
NS Nisling
PC Porcupine
PERICRATONIC
KO Kootenay
SUBTERRANES
KO? Kootenay - inferred
KO$_B$ Barkerville
KO$_N$ Nisutlin
PG Pelly Gneiss
ACCRETED TERRANES
INTERMONTANE SUPERTERRANE
SM Slide Mountain
DY Dorsey
QN Quesnellia
SUBTERRANES
QN$_H$ Harper Ranch
QN$_O$ Okanagan
CC Cache Creek
ST Stikinia
WM Windy McKinley
WR Wrangellia
OUTER TERR
CG Chugach
YA Yakutat
PR Pacific Rim
CR Crescent
OC Olympic Core
OZ Ozette
HO Hoh
ROCKS EXCLUD
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TR$_L$ Lewes River (
J$_{BL}$ Bowser Lake (
J$_I$ Inklin (on Cac
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JK$_G$ Gambier (in C
POST-TERRANE AC
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Q Quaternary
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● PRECIOUS METAL ENRICHED (PME) SKAR
▲ PRECIOUS METAL ENRICHED (PME) SKAR PRODUCER
NOTE: SKARN LOCATION NUMBERS REFER TO N OF APPENDIX 1
PACIFIC
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QUEEN CHARLOTTE SOUND
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INTERMONTANE BELT
EAST
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OMINECA
BRITISH COLUMBIA
ALBERTA
Dawson Creek
Mackenzie
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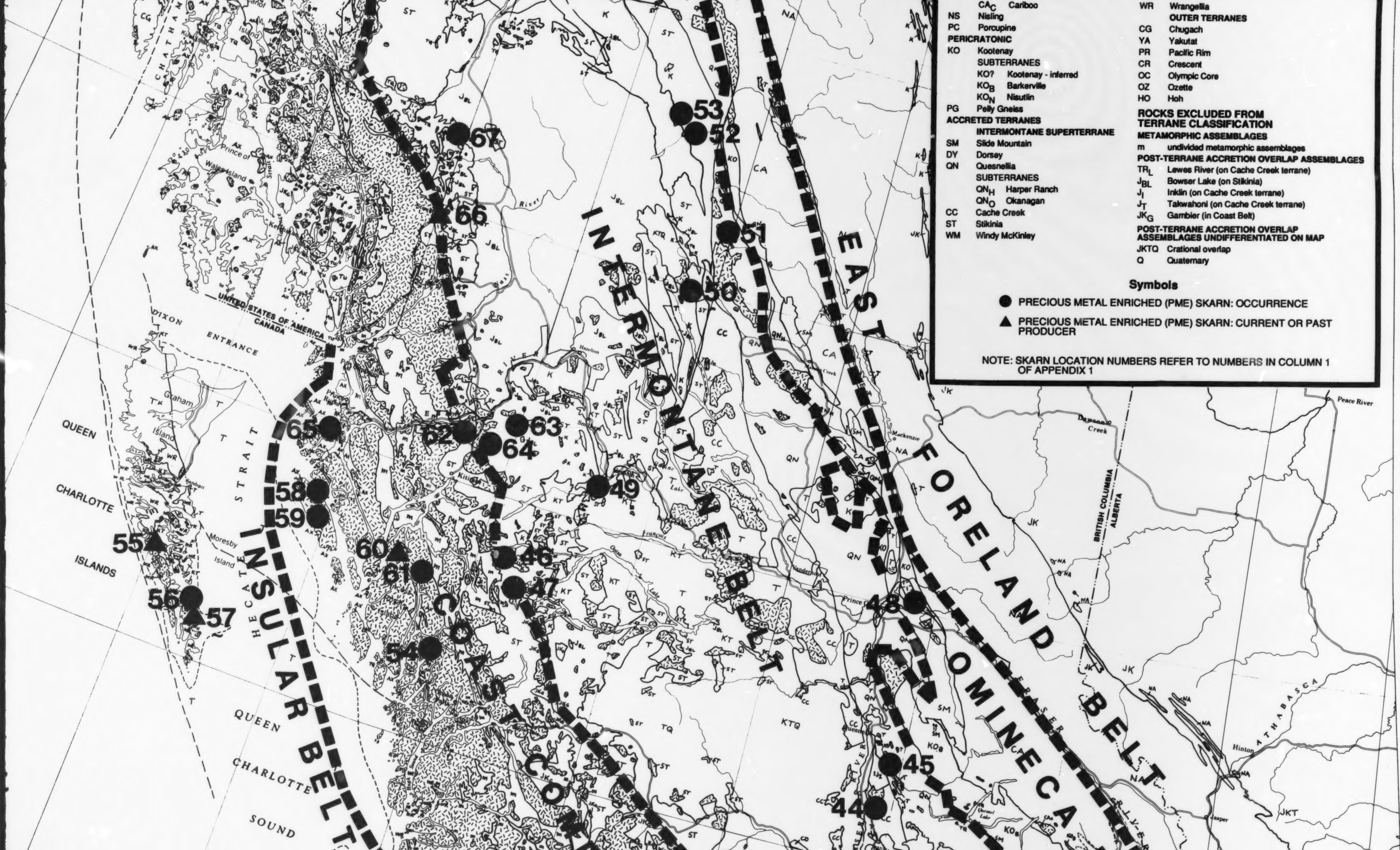
CA$_C$ Cariboo
NS Nisling
PC Porcupine
PERICRATONIC
KO Kootenay
SUBTERRANES
KO? Kootenay - inferred
KO$_B$ Barkerville
KO$_N$ Nisutlin
PG Pelly Gneiss
ACCRETED TERRANES
INTERMONTANE SUPERTERRANE
SM Slide Mountain
DY Dorsey
QN Quesnellia
SUBTERRANES
QN$_H$ Harper Ranch
QN$_O$ Okanagan
CC Cache Creek
ST Stikinia
WM Windy McKinley
WR Wrangellia
OUTER TERRANES
CG Chugach
YA Yakutat
PR Pacific Rim
CR Crescent
OC Olympic Core
OZ Ozette
HO Hoh
ROCKS EXCLUDED FROM TERRANE CLASSIFICATION
METAMORPHIC ASSEMBLAGES
m undivided metamorphic assemblages
POST-TERRANE ACCRETION OVERLAP ASSEMBLAGES
TR$_L$ Lewes River (on Cache Creek terrane)
J$_{BL}$ Bowser Lake (on Stikinia)
J$_I$ Inklin (on Cache Creek terrane)
J$_T$ Takwahoni (on Cache Creek terrane)
JK$_G$ Gambier (in Coast Belt)
POST-TERRANE ACCRETION OVERLAP ASSEMBLAGES UNDIFFERENTIATED ON MAP
JKTQ Crational overlap
Q Quaternary
Symbols
● PRECIOUS METAL ENRICHED (PME) SKARN: OCCURRENCE
▲ PRECIOUS METAL ENRICHED (PME) SKARN: CURRENT OR PAST PRODUCER
NOTE: SKARN LOCATION NUMBERS REFER TO NUMBERS IN COLUMN 1 OF APPENDIX 1
INSULAR BELT
COAST COMPLEX
INTERMONTANE BELT
OMINECA BELT
EAST FORELAND BELT
UNITED STATES OF AMERICA
CANADA
BRITISH COLUMBIA
ALBERTA
DIXON ENTRANCE
QUEEN CHARLOTTE ISLANDS
HECATE STRAIT
QUEEN CHARLOTTE SOUND
Prince of Wales Island
Graham Island
Moresby Island
CHATHAM
Hazelton
Prince George
Quesnel
Mackenzie
Dawson Creek
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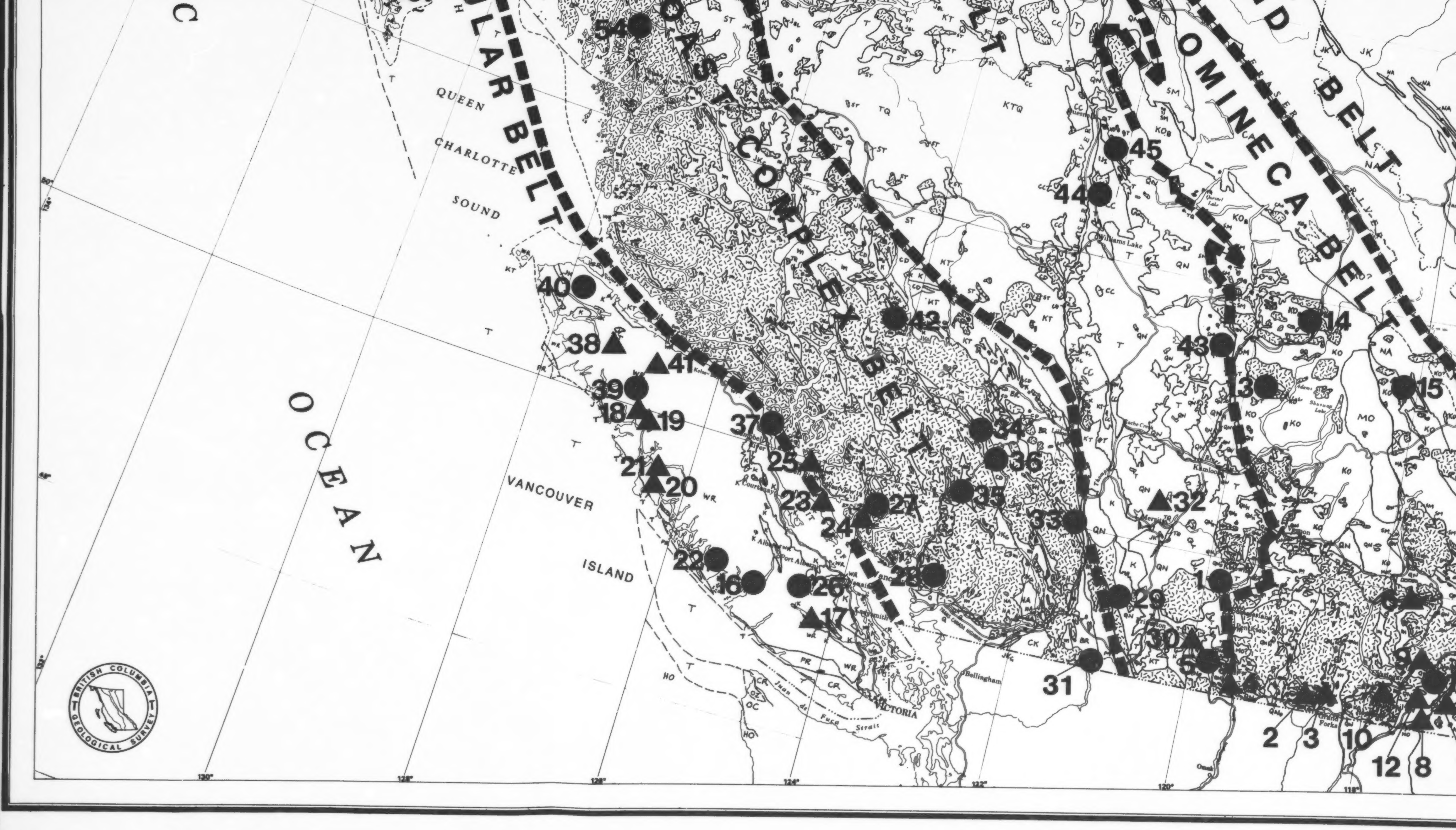
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VICTORIA
Bellingham
Williams Lake
Quesnel
Kamloops
Merritt
Courtenay
Port Alberni
Nanaimo
Omak
Grand Forks
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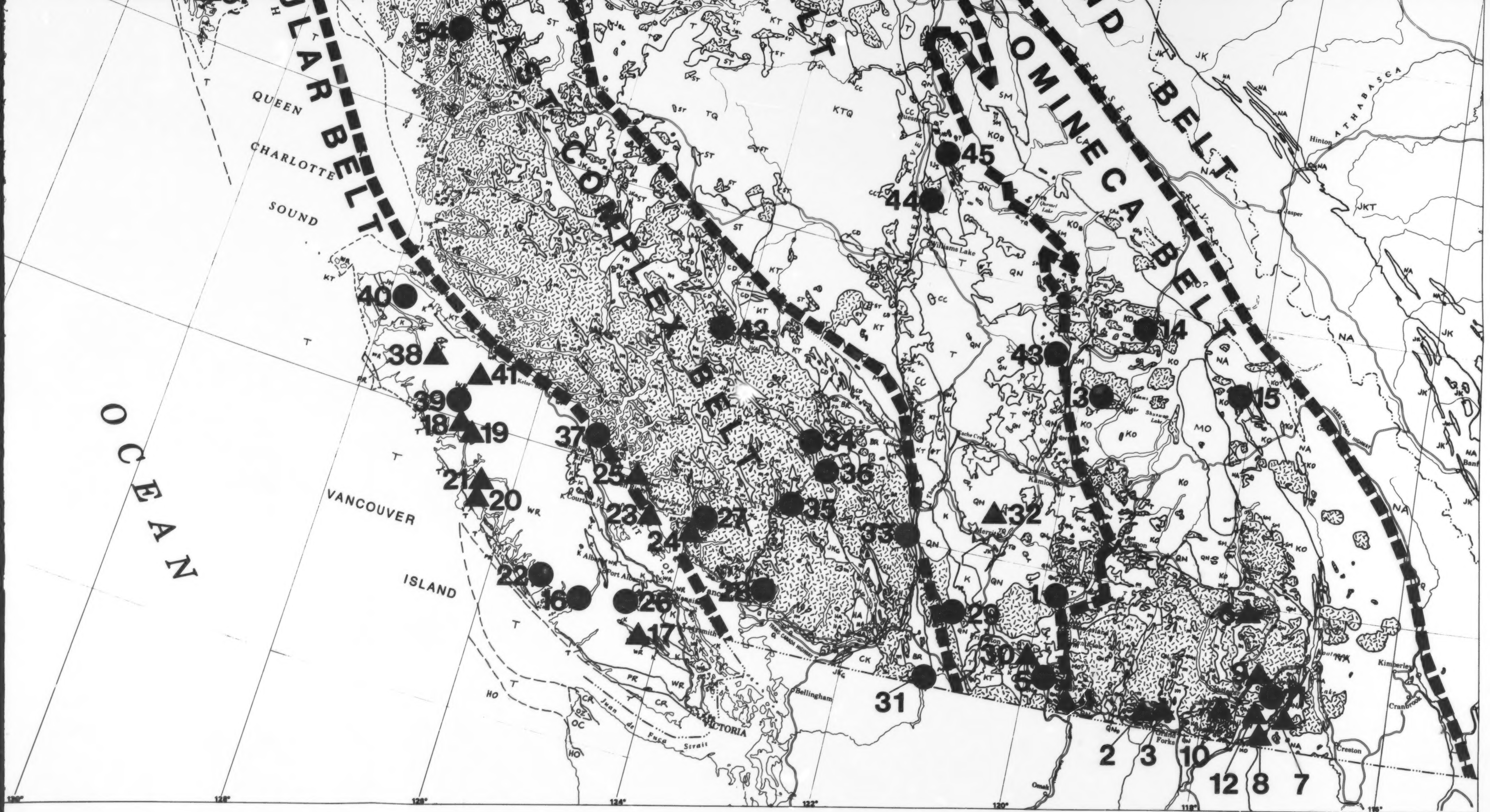
INSULAR BELT
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Williams Lake
Kamloops
Merritt
Princeton
Grand Forks
Creston
Cranbrook
Kimberley
Hinton
Jasper
Banff
ATHABASCA
FRASER RIVER
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TO ACCOMPANY PAPER 198